US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report 95/26
August 1995

Central Heating Plant Modernization

A Study Done for Fort Dix, NJ

by
Michael K. Brewer, Martin J. Savoie, Travis L. McCammon, and Charles Schmidt

The facilities at Fort Dix, NJ include three central heating plants, one laundry steam plant, and one heat recovery incinerator facility. The age and condition of the installation's energy plants stimulated an investigation of possible alternatives to provide the installation's needed thermal energy. This report documents preliminary results of a U.S. Army Construction Engineering Research Laboratories (USACERL) study to identify cost-effective technologies to meet current and future thermal and electrical energy needs at Fort Dix.

The study assessed the capabilities of the thermal production plant and the economic feasibility of using two hot water distribution systems in comparison with the two steam distribution options that bracket the current production situation. It was concluded that large savings may be realized using the existing equipment, repaired to improve efficiency. If a new central energy infrastructure is to be built or major capital investment is needed for the current plant, low temperature hot water would be the lowest life-cycle central plant option. Due to the low thermal usage density, distributed energy alternatives should also be considered.

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REPORT DOCUMENTATION PAGE

Form Approved
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1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
August 1995

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Central Heating Plant Modernization: A Study Done for Fort Dix, NJ

5. FUNDING NUMBERS
MIPRs
JE 72-92 (September 1992)
DPW 036-93 (February 1993)

6. AUTHOR(S)
Michael K. Brewer, Martin J. Savoie, Travis L. McCammon, and Charles Schmidt

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 95/26

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U.S. Army Forces Command (HQFORSCOM)
ATTN: FCEN-RDF
Fort McPherson, GA 30330-6000

Directorate of Public Works (DPW)
ATTN: ATZD-EHW
Bldg. 5320
Fort Dix, NJ 08640-5505

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The facilities at Fort Dix, NJ include three central heating plants, one laundry steam plant, and one heat recovery incinerator facility. The age and condition of the installation's energy plants stimulated an investigation of possible alternatives to provide the installation's needed thermal energy. This report documents preliminary results of an U.S. Army Construction Engineering Research Laboratories (USACERL) study to identify cost-effective technologies to meet current and future thermal and electrical energy needs at Fort Dix.

The study assessed the capabilities of the thermal production plant and the economic feasibility of using two hot water distribution systems in comparison with the two steam distribution options that bracket the current production situation. It was concluded that large savings may be realized using the existing equipment, repaired to improve efficiency. If a new central energy infrastructure is to be built or major capital investment is needed for the current plant, low temperature hot water would be the lowest life-cycle central plant option. Due to the low thermal usage density, distributed energy alternatives should also be considered.

14. SUBJECT TERMS
central heating plants
energy efficiency
life cycle costs
maintenance and operation

15. NUMBER OF PAGES
102

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for Headquarters, U.S. Army Forces Command (HQ-FORSCOM) and the Fort Dix Directorate of Public Works (DPW) under Military Interdepartmental Purchase Request (MIPR) No. JE 72-92, dated September 1992, and DPW 036-93, dated 11 February 1993. The technical monitors were Adrian Gillespie, FCEN-RDF and Steven Whitmore, ATZD-EHW.

The work was performed by the Utilities Division (UL-U) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). Special appreciation is expressed to the public works staff at Fort Dix, NJ, for their assistance in collecting data and doing site surveys. Martin J. Savoie is Acting Chief, CECER-UL-U, John T. Bandy is Operations Chief, CECER-UL, and Gary W. Schanche is Chief, CECER-UL. The USACERL technical editor was William J. Wolfe, Information Management Office.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

The facilities at Fort Dix, NJ include three central heating plants (CHPs), one laundry steam plant, and one heat recovery incinerator (HRI) facility. The boilers at the two largest CHP's are between 30 and 40 years old, an age when normal wear and the increased efficiencies of newer technologies make equipment upgrade or replacement both cost-effective and necessary.

The age and condition of the energy plants at Fort Dix (Table 1) stimulated an investigation of possible alternatives to provide the needed thermal energy to the installation. Fort Dix installation management began investigating modernization opportunities for its CHPs, and Headquarters, Forces Command (HQFORSCOM) requested that the U.S. Army Construction Engineering Research Laboratories (USACERL) study the situation to help determine the most feasible options to improve the installation's energy supply. This report documents preliminary results of a study to investigate alternatives to modernize the energy plants at Fort Dix.

Objective

The objective of this study was to identify the most cost effective technologies to meet current and future thermal and electrical energy needs at Fort Dix.

Table 1. Heating plants servicing building areas 5200, 5400-5900, and building 5324.

Building	No. Boilers	Boiler Capacity (lb/hr)	Manufacturer	Fuel	Year Built
5252 (Hospital)	3	40,000	Bigelow	No. 6 Oil	1958
5324 (Laundry)	2	28,000	Murray Iron	No. 4 Oil/N.Gas	1972
5426	3	50,000	Erie	No. 6 Oil	1953
5426	1	50,000	Keeler	No. 6 Oil	Unavailable
5881	4	50,000	Keeler	No. 6 Oil	1964/65
HRI	2	8,500	Unavailable	Refuse	1986

Approach

Information on file at Fort Dix taken from installation-supplied information, in-house reports, and operation records was analyzed and verified to establish baseline conditions. A visual inspection was made of CHP equipment and the steam distribution system to assess baseline operating conditions and problem areas.

Next, the energy use patterns of Fort Dix were analyzed, including current thermal and electrical energy demand, heating load, and usage patterns, for current and future energy use for the facility. A variety of prediction methods were used depending on the specific energy pattern being investigated.

Based on the energy use pattern analysis, potential thermal energy supply options were identified. These options were evaluated in terms of cost, efficiency, and reliability, considering both equipment and upgrade costs and regionally available and appropriate fuel supplies. Thermal and energy supply options were evaluated for cost and reliability.

Based on these findings, life-cycle cost analyses were developed for three scenarios: (1) maintaining the status quo (no change), (2) installing a new or upgraded steam system, and (3) installing a new, pressurized hot water system. Further options within these alternatives were considered to further improve the life cycle costs.

Software Used

The following software was used to model and analyze the energy plant systems at Fort Dix. Citation of trade names is not meant to construe official endorsement or approval of any commercial products.

Program	For further information:
BLAST	J.A. Amber, D.J. Leverenz, and D.L. Herron, *Automated Building Design Review Using BLAST*, USACERL Technical Report (TR) E-85/03/ADA151707 (U.S. Army Construction Engineering Research Laboratory [USACERL], January 1985).
DOE2	*DOE-2.1*, TR LBL-34947/NTIS Report DE94-011218 (Energy and Environmental Division, Lawrence Berkely Laboratories, University of California, Berkeley, CA, November 1993).
HEATLOAD	R.E. Moshage, R. Januzik, R. Flanigan, and W. Scherer, *Heating Plant Options Economic Analysis System (HPECON) User's manual and Technical Reference*, Automated Data Processing (ADP) Report E-91/04/ADA234030 (USACERL, March 1991).

Program	For further information:
HEATMAP	*HEATMAP 2.0* (Washington State Energy Office, 925 Plum Street SE, Bldg. 4, Olympia, WA, December 1994).
LICHEAT	*LICHEAT 3.0* Manual No. 1993-01-11(LICconsult A/S, Bregnerødvej 90, 3460 Birkerød, Denmark, January 1993).
SHDP	James A. Miller and David Am Wasserman, *Steam Heat Distribution Program User's Manual*, Technical Manual (TM) M-73-89-01CR (Naval Civil Engineering Laboratory, Port Hueneme, CA, August 1989).

Metric Conversion Factors

The following metric conversions are provided for standard units of measure used throughout this report:

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) +32

2 Existing Steam Supply Systems

Central Heating Plants (CHPs)

CHPs 5881 and 5426 provide the majority of the steam to the distribution system to buildings in areas 5200, and 5400 to 5900. The plant adjacent to the hospital (CHP 5252) is rarely operated. The laundry is supplied by its own boiler plant in CHP 5324. The heat recovery incinerator (HRI) is adjacent to CHP 5881 and connected to the steam supply header.

CHP 5252

CHP 5252, located adjacent to the hospital (Bldg 5250), consists of three Bigelow watertube boilers installed in 1958. The plant is rarely operated. Its current control system requires manual operation. Table 2 lists additional boiler data for CHP 5252.

Table 2. Boilers installed in CHP 5252.

Bldg	Boiler Ser. No.	Boiler Cap. (lb/hr)	Manuf.	Fuel	Year Built	Press. (psig)	Heating Surface (sq ft)	Tube Dia.	No. of Tubes	BHP
5252	NB-1630	40,000	Bigelow	#6 Oil	1958	160	5574	2	789	1015
5252	NB-1631	40,000	Bigelow	#6 Oil	1958	160	5574	2	789	1015
5252	NB-1632	40,000	Bigelow	#6 Oil	1958	160	5574	2	789	1015

CHP 5324

CHP 5324, which supplies steam to only the laundry, has two Murray Iron watertube boilers. The plant operates primarily during working hours. On weekends and evenings, the plant is shut down unless there is a building heating requirement. Table 3 summarizes boiler data for CHP 5324.

Table 3. Boilers installed in CHP 5324.

Bldg	Boiler Ser. No.	Boiler Cap. (lb/hr)	Manuf.	Fuel	Year Built	Press. (psig)	Heating Surface (sq ft)	Tube Dia.	No. of Tubes	BHP
5324	NB-10323	28,000	Murray Iron	#4 Oil/Gas	1972	250	4379	2	867	875
5325	NB-10324	28,000	Murray Iron	#4 Oil/Gas	1972	250	4379	2	867	875

CHP 5426

CHP 5426 has three Erie City Iron Works watertube boilers and one Keeler watertube boiler. This plant primarily services the northern half of the steam heating distribution system. The Keeler boiler was taken out of service since the steam-driven fans were no longer operated. CHP 5426 can also provide steam to the southern half of the steam system during the summer. Table 4 summarizes boiler data for CHP 5426. The Erie City Iron Works boilers originally fired coal, but have since been converted to fire No. 6 oil. The oil burners are located on the lower front wall of the boiler below the water wall header.

Table 4. Boilers installed in CHP 5426.

Building	Boiler Ser. No.	Boiler Cap. (lb/hr)	Manuf.	Fuel	Year Built	Press. (psig)	Heating Surface (sq ft)	Tube Dia.	No. of Tubes	BHP
5426	NB-14488	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	NB-14489	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	NB-14490	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	—	50,000	Keeler	#6 Oil	—	—	—	—	—	—

CHP 5881 and HRI

CHP 5881 and the HRI service the southern half of the steam distribution system. Table 5 summarizes boiler data for CHP 5881. The boilers were designed as coal stoker boilers, but were modified during installation to fire No. 6 oil. The burners are located in the middle of the side walls of the boilers. The coal handling equipment is not present.

Table 5. Boilers installed in CHP 5881.

Building	Boiler Ser. No.	Boiler Cap. (lb/hr)	Manuf.	Fuel	Year Built	Press. (psig)	Heating Surface (sq ft)	Tube Dia.	No. of Tubes	BHP
5881	NB-3978	50,000	Keeler	#6 Oil	1964	160	8495	2.5	958	1633
5881	NB-3979	50,000	Keeler	#6 Oil	1964	160	8495	2.5	958	1633
5881	NB-4077	50,000	Keeler	#6 Oil	1964	160	8495	2.5	958	1633
5881	—	50,000	Keeler	#6 Oil	1964	160	8495	2.5	958	1633

Steam Distribution System

The CHP provides steam for heating and process loads to 197 buildings though steam lines. The steam lines system can be divided into six service areas. The total steam distribution system measures about 87,100 linear feet. Figure 1 shows the main distribution system areas. A visual inspection was made of five pits and four building equipment rooms. The following observations were recorded:

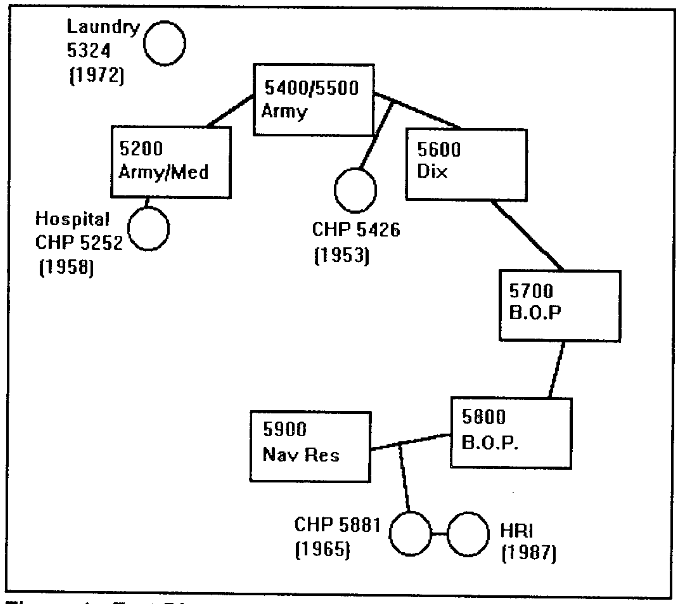

Figure 1. Fort Dix steam distribution system and building areas.

- Visual inspection of steam traps in pits showed them to be in good condition.
- One pit had water, vent pipe cutoff flush with ground.
- Two pits had steam leaks.
- One building had a steam leak.
- Shallow trench settling at a different rate than the pit had caused spalling of pit structure.
- Ricwil condensate piping has needed replacement in all pits visited (Figures 2 and 3).

In general, the traps in the pits that had structural integrity and water intrusion control appeared to be well maintained. However, equipment in the building mechanical spaces appeared to need maintenance and repair. Some of the problems may be rooted in the sporadic use of the facilities by the tenants. It is possible building tenants are not reimbursing public works at a level appropriate to keeping the mechanical spaces in good condition.

The condensate return system may be in need of capital investment based on sample visual inspections and the amount of condensate returned to the CHPs. The inconsistencies in the logged data about feedwater and makeup usage could account for a factor of ten difference. The data as recorded for each plant are plotted in Figures 4, 5, and 6. The steam flow estimates and/or makeup flow metering may be in error at CHPs 5881 and 5426. When compared to other DOD distribution systems, the 100-percent makeup rate at CHP 5881 seems excessive while the 11-percent makeup rate at CHP 5426 seems low. The logs indicate an average makeup rate of 9800 gal per day for all three CHPs. If the makeup rates are as excessive as recorded, the increase in

continuous blowdown necessary to control dissolved solids will be a major thermal loss for the boilers. In the interim, the steam and water management instrumentation should be validated or repaired. This information will help quantify the distribution system's effectiveness.

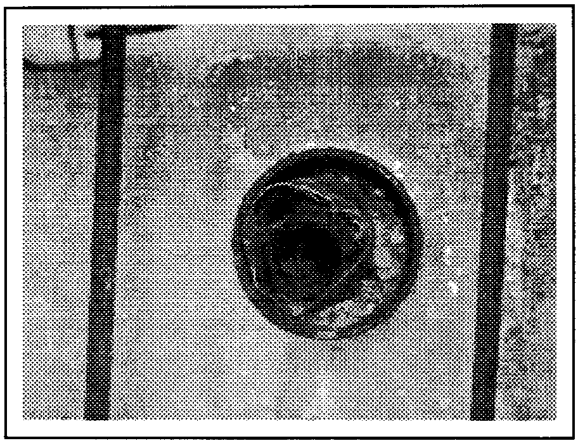

Figure 2. Old Ricwil-type condensate line.

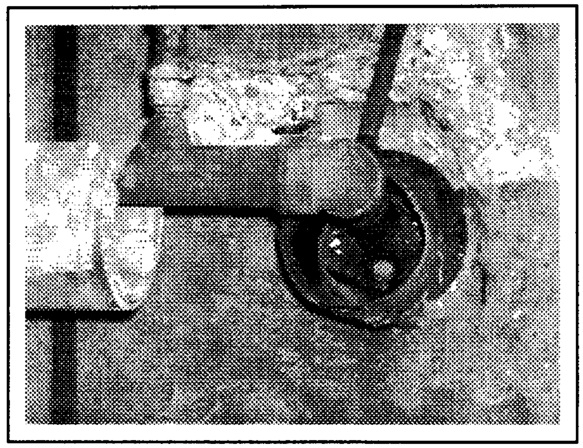

Figure 3. Steam line above abandoned condensate line.

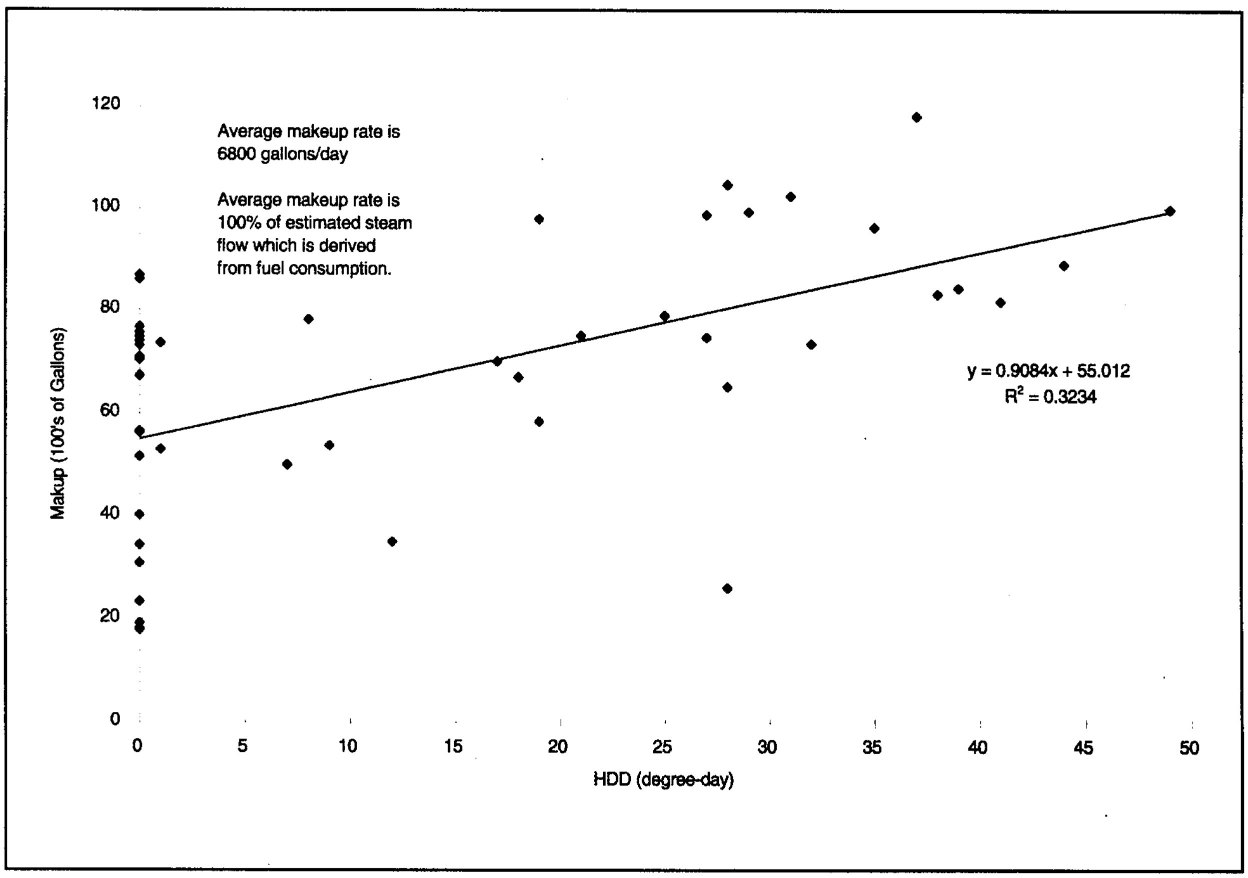

Figure 4. Makeup rate versus heating degree-days for CHP 5881.

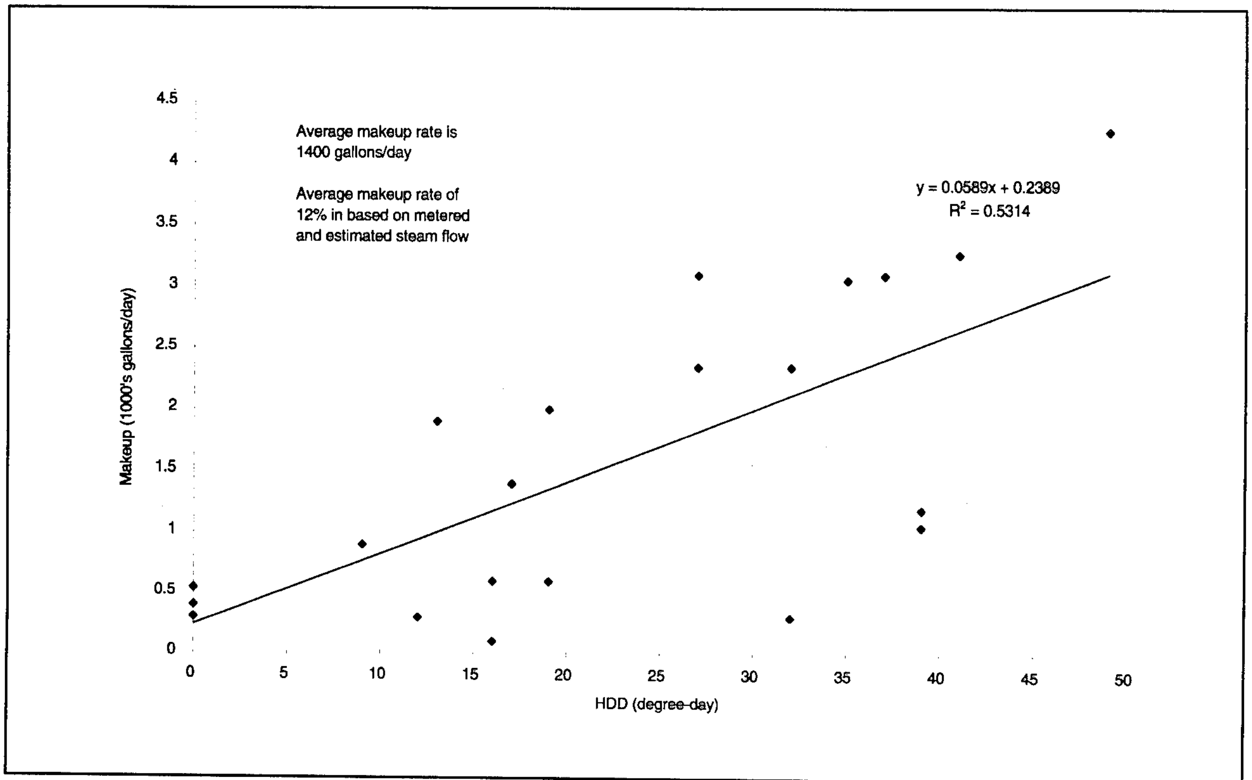

Figure 5. Makeup rate versus heating degree-days for CHP 5324.

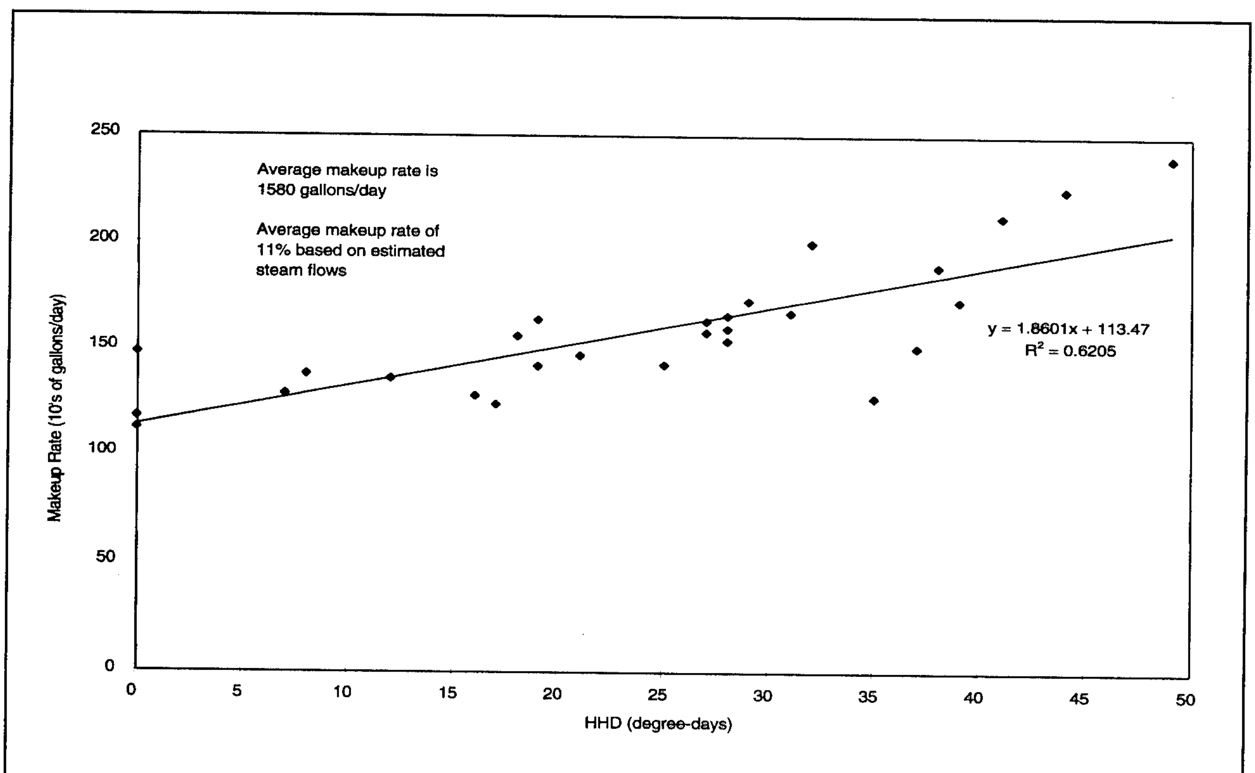

Figure 6. Makeup rate versus heating degree-days for CHP 5426.

3 Thermal Energy Supply and Consumption

Central Heating Plant Steam Load

CHP personnel record plant performance on DA Form 3995, *Daily Boiler Plant Operating Log* (Assistant Chief of Staff for Installation Management [ACSIM], December 1972), and the (now obsolete) DA Form 3967, *Monthly Boiler Plant Log Summary*. The monthly logs for the calendar year 1992 (CY92) were collected and analyzed to quantify plant performance as a function of heating degree-day (HDD). Most of the steam flows logged were estimates based on fuel oil consumption. This method of steam flow measurement can add significant errors especially when at low load or transient conditions. Random samples out of each week (7-day sampling interval) were plotted for each plant. The gross steam thermal output (energy produced at the steam stop) was plotted since there was a lack of steam meter data and plant steam load information. The plant thermal output was also corrected for the variation in steam pressure.

CHP 5324 Steam Load

Figure 7 shows a plot of thermal production at CHP 5324 for CY92. CHP 5324 serves only the base laundry facility. The process load in 1992 was only about 3500 lb of steam/hr (3-4000 MBTU/hr). The combined heating and process load during the winter averages less than 7500 lb of steam/hr (7-8000 MBTU/hr). These loads are very near the turndown limit for the 28,000 lb/hr boilers in CHP 5324. As a result, the fuel-to-steam conversion will not be optimal for these boilers. Additionally, the laundry is replacing steam-heated equipment with electrically heated equipment resulting in further losses in thermal economy.

CHP 5426 Steam Load

Figure 8 shows a plot of thermal production at CHP 5426 for CY92. CHP 5426 primarily serves the Army, Coast Guard, U.S. Air Force and other government agencies building areas (areas 5600, 5500, 5400, and 5200). The plant associated with the hospital, CHP 5252, is very rarely used to maintain header pressure in the 5200

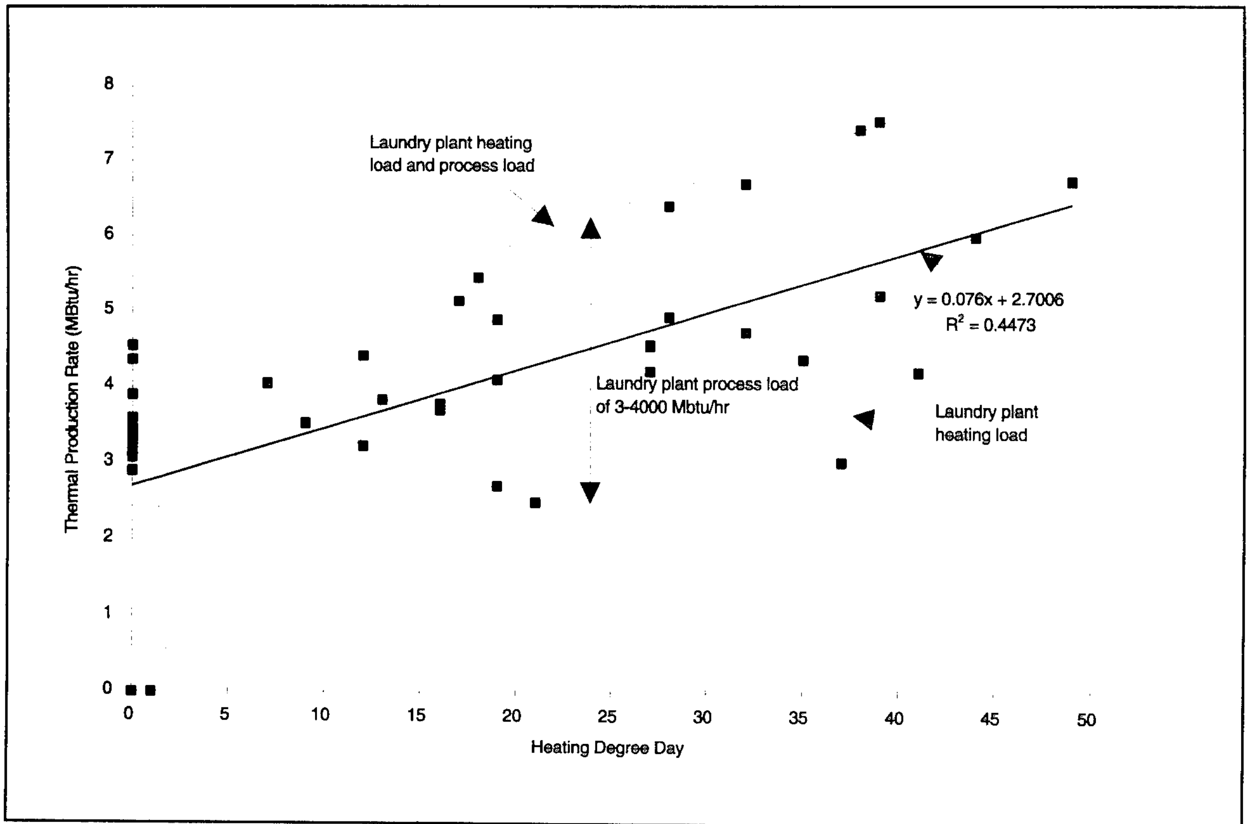

Figure 7. CHP 5324 thermal production CY92.

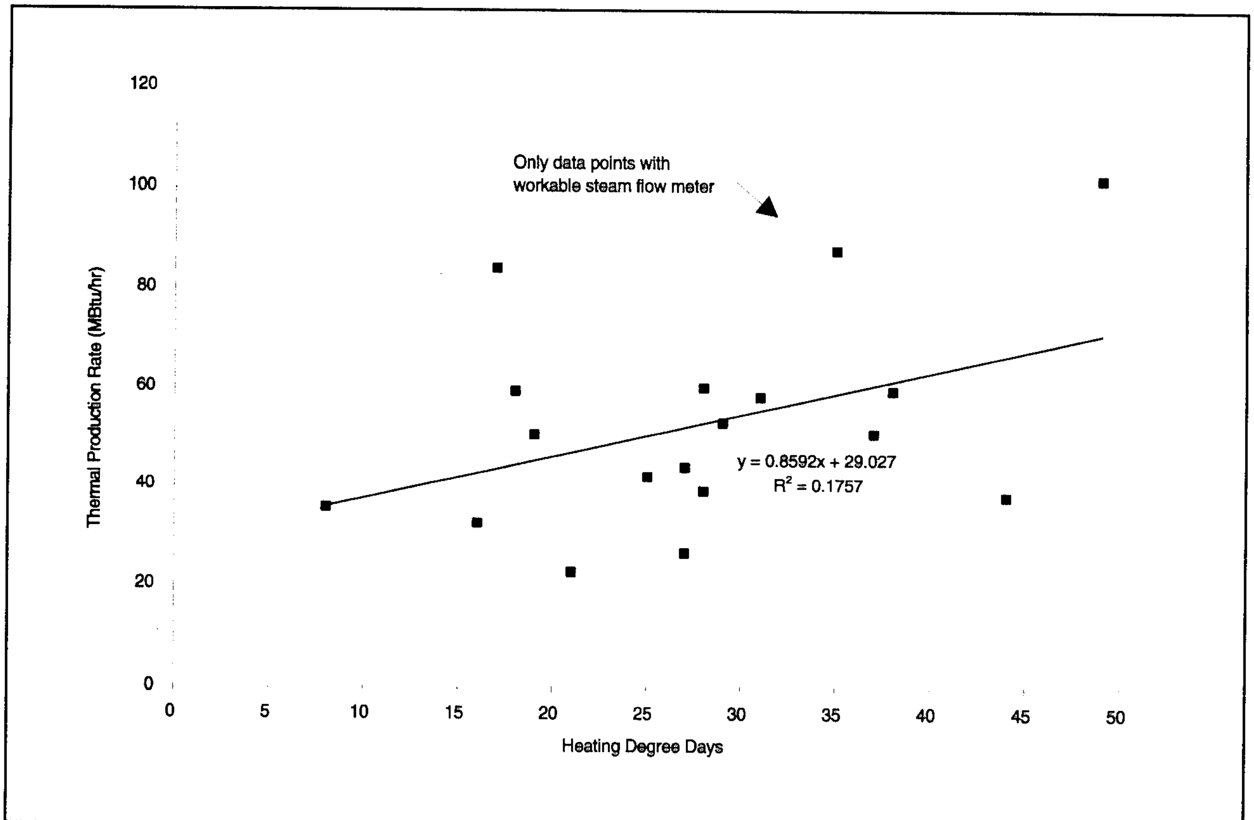

Figure 8. CHP 5426 thermal production CY92.

building area. CHP 5426 serves the 5200 area with a cross-connect line to CHP 5252. CHP 5426 was shut down during the summer of 1992 for repairs, but there were still enough low HDD days data points to indicate that a large system loss or summer load of 30,000 MBTU/hr exists.

CHP 5881 Steam Load

Figure 9 shows a plot of thermal production at CHP 5881 for CY92. CHP 5881 primarily serves the Bureau of Prisons and Naval Reserve Center building areas (areas 5900, 5800, and 5700). Although only one boiler is needed to handle routine winter loads, when many of the vacant buildings become occupied, as seen during the Fall of 1992, the load almost doubles. The HRI also augments the steam supplied by 5881, but its production rate is determined by the amount of burnable refuse available (Figure 10). Only two of the four installed boilers in CHP 5881 are available for service. Loss of one of the two remaining boilers would make it difficult to serve the customers in areas 5900, 5800, and 5700 during a winter mobilization.

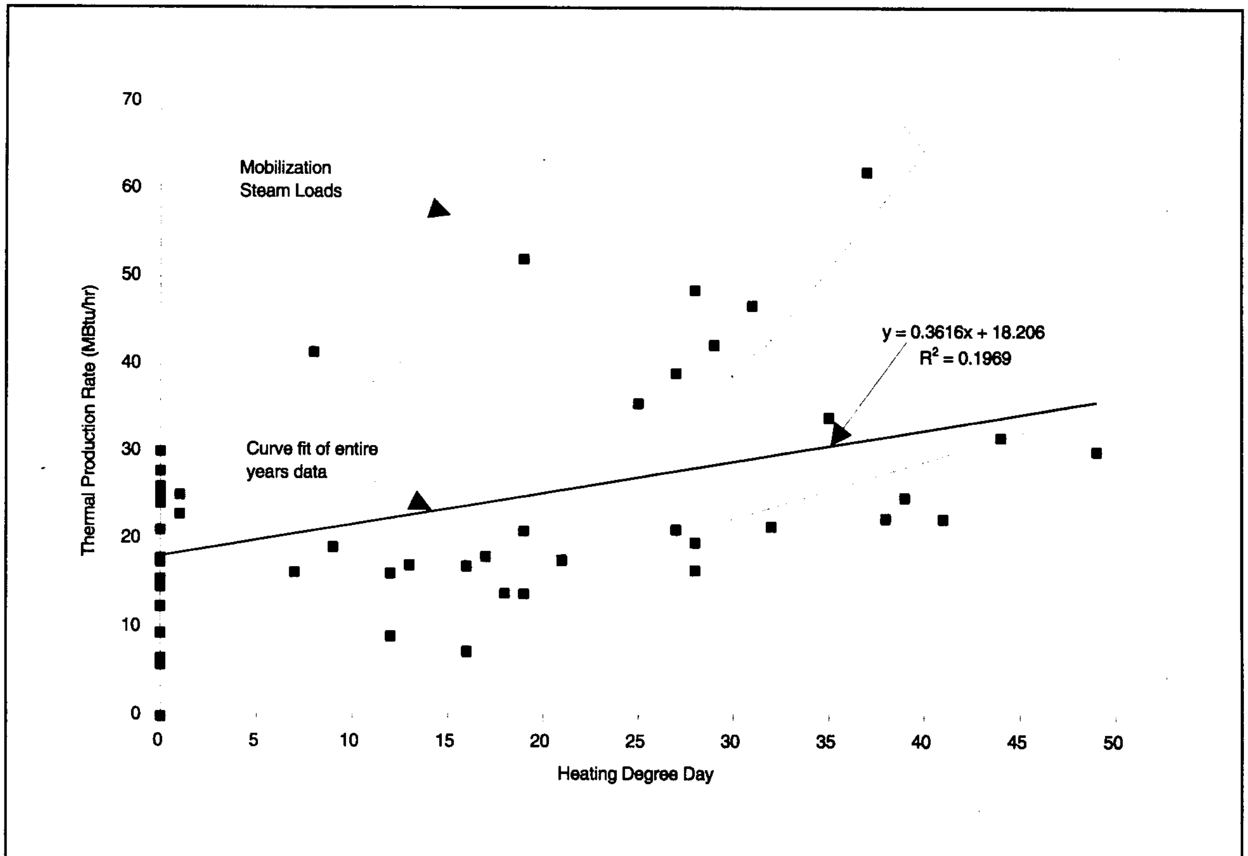

Figure 9. Thermal production for CHP 5881, CY92.

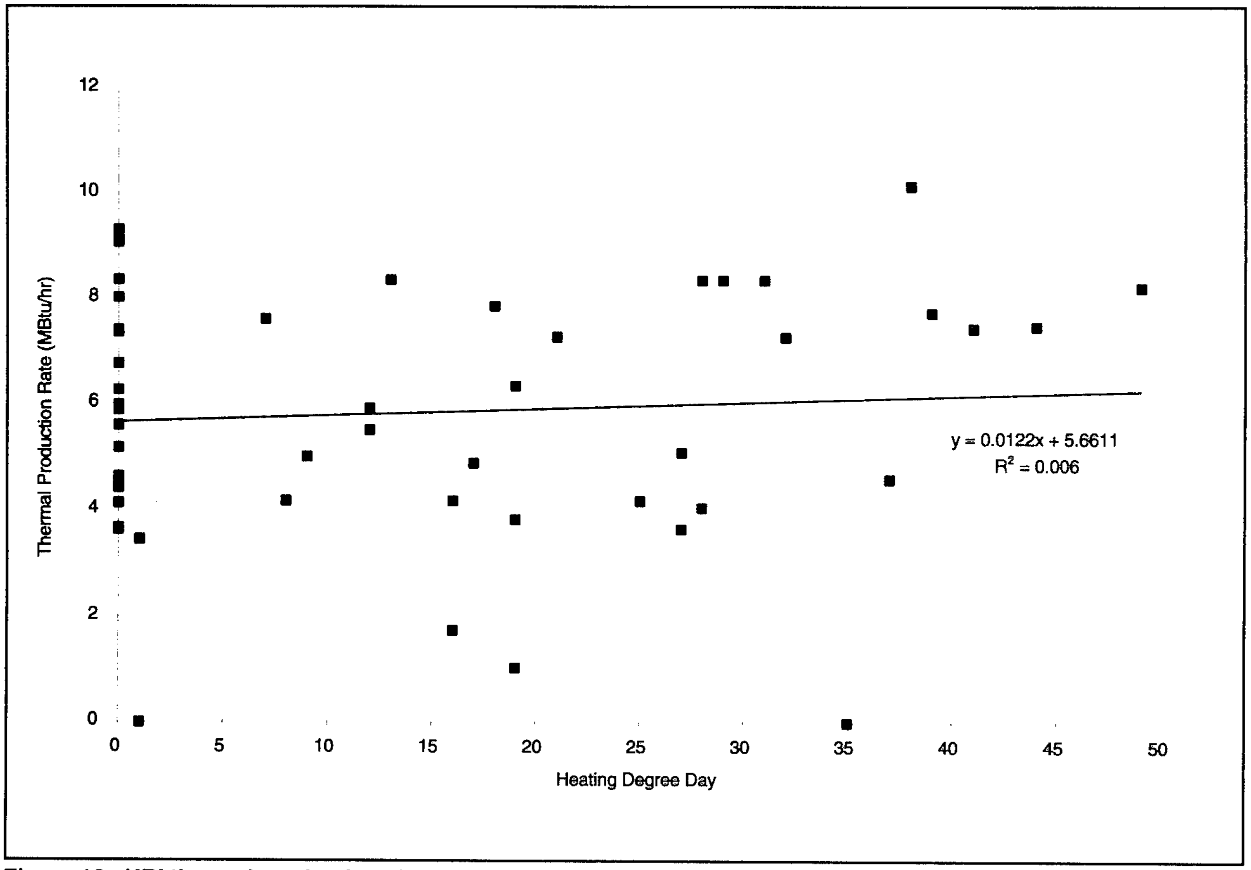

Figure 10. HRI thermal production, CY92.

Steam End Use

The majority of the steam consumption at Fort Dix is used to generate hot water for building heat units and to produce domestic hot water. There are some steam process loads at the laundry and the hospital. A review of the real property data indicated most of the cooling units are vapor compression cycle equipment. The potential steam consumption was modeled to provide a check on the estimated steam flow. The model will also help define the steam consumption envelope since many buildings are only partially occupied unless a mobilization occurs.

HEATLOAD

The HEATLOAD program, developed by USACERL, provides a simple method of calculating building heat requirements. Other computer programs such as BLAST or DOE2 can provide more accurate analysis, but require much more information to develop a heat load estimate. Experience with HEATLOAD has shown it to be quite accurate for estimating installation-wide building heat requirements for central energy plant alternatives.

HEATLOAD is based on a series of linear regressions developed from heating use measurements at typical facilities on several Army installations. The facility categories and regressions are listed in Table 6. Each building type has a corresponding daily heating energy consumption equation in the form of:

$$E_h = a1 + (b1 \times HDD_d) \qquad \text{[Eq 1]}$$

where a1 and b1 are regression parameters. The symbol "Eh" is the daily heating energy consumption (BTU/sq ft/day) and HDDd is the daily heating degree day.

The regression parameter a1 is a constant that represents energy usage that occurs for zero HDD and reflects nonheating loads such as hot water and cooking. The regression parameter b1 is the heating load parameter. Building categories and area (sq ft) are obtained from real property data files.

The climatological data required for HEATLOAD, such as the historical average HDD and the design temperature, are obtained from the Army Technical Manual (TM) 5-785, 1978, "Engineering Weather Data" or directly from the USAF Environmental Technical Applications Center (ETAC) at Scott AFB, IL. With this information, HEATLOAD will calculate the peak hourly heating load, average monthly loads, maximum monthly loads, and total annual heating load.

Distribution System Losses

A steam distribution system typically consists of steam generators, pipes, regulators, valves, and traps. Steam enters the system at the steam plant, passes through pipes,

Table 6. Building categories and energy consumption equations.

Building Type	Type Code	HEATLOAD Equation (E_h: BTU/sq ft-day)
Troop Housing Barracks	B1	Eh = 130.50 + (10.53 x HDDd)
Troop Housing Barracks (after 1966)	B2	Eh = 81.91 + (7.40 x HDDd)
Troop Housing Barracks (modular)	B3	Eh = 295.90 + (10.53 x HDDd)
Dining Facilities	D	Eh = 241.90 + 0
Family Housing	FAM	Eh = 113.5 + (10.53 x HDDd)
Administration/Training	A,T	Eh = 75.71 + (7.02 x HDDd)
Medical/Dental	MED	Eh = 254.40 + (11.41 x HDDd)
Storage	W	Eh = 35.70 + (10.53 x HDDd)
Production/Maintenance	P/M	Eh = 138.25 + (10.53 x HDDd)
Recreation	REC	Eh = 231.5 + (5.3 x HDDd)
Commissary	C	Eh = 147.0 + (7.02 x HDDd)
NCO/Officers Club	NCO	Eh = 231.5 + (8.75 x HDDd)
Fieldhouses/Gymnasiums	GYM	Eh = 73.69 + (4.39 x HDDd)

valves, and regulators, and is delivered to the buildings. The steam loses heat through pipe walls by conduction. As the steam passes through the pipes, regulators, and valves, the steam pressure drops. Condensate formed in the pipes is removed from the system through steam traps and a condensate piping system. The amount of energy lost from the steam distribution system can be substantial.

One way of estimating the distribution losses is to look at the lowest hourly steam flow during the summer months. This technique only works if there are no substantial summer steam loads. To look at the total steam distribution historical performance, the thermal production of CHP 5426, CHP 5881, and the HRI were combined (Figure 11). Figure 11 shows the average zero heating degree-day steam demand to be about 30,000 lb steam/hr, indicating that the distribution losses are about 30,000 lbs steam/hr. Determining the lowest summer load by analyzing steam load data is a good method to estimate distribution losses, but is not very rigorous. To better quantify these losses, this study used a computer model called the Steam Heat Distribution Program (SHDP) to analyze distribution system losses.

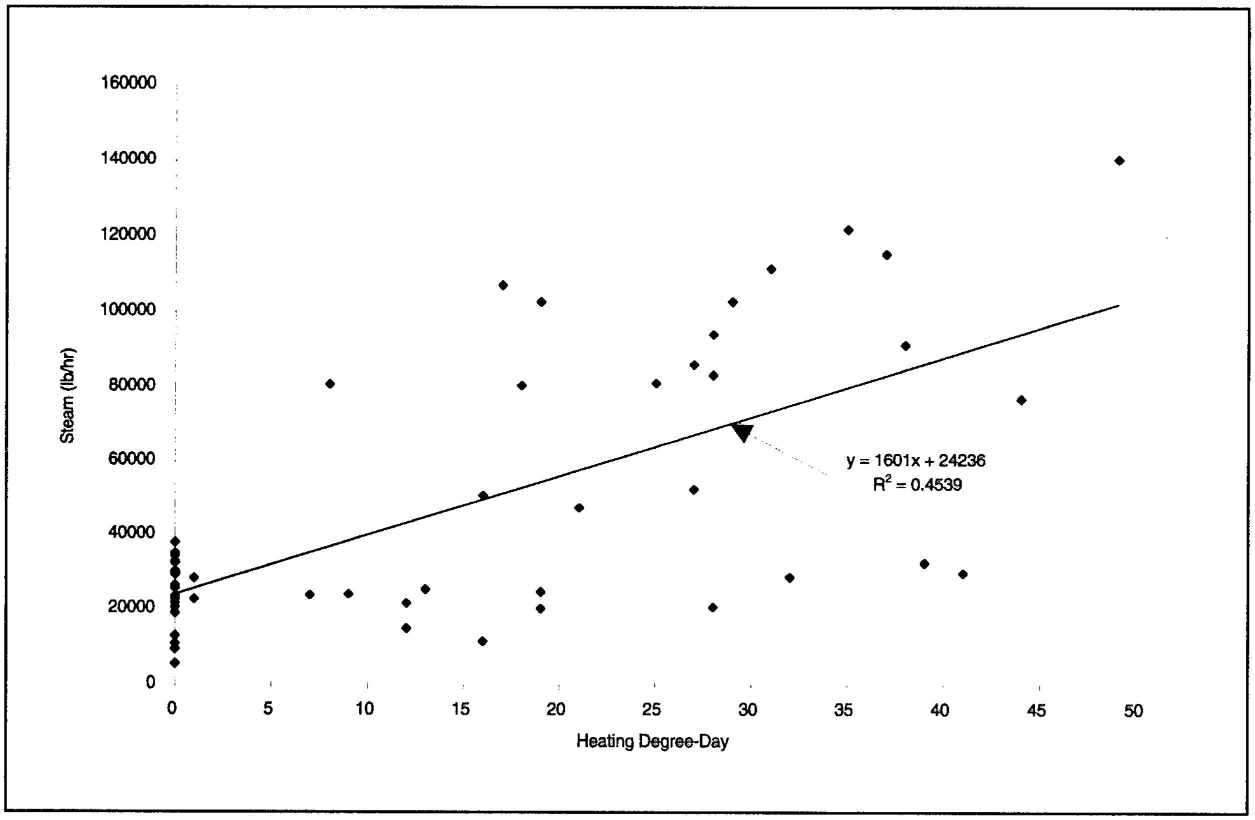

Figure 11. Total steam distribution system production, CY92.

SHDP Analysis

SHDP is a pressure-flow-thermal efficiency computer program for modeling steam district heating systems. The program has several capabilities, including: (1) design and economic evaluation of manhole renovation, and modifications or additions to existing distribution systems and (2) economic evaluation of operating at lower pressures and improved maintenance of steam traps. In this study, SHDP was primarily used to estimate distribution losses.

To use SHDP, the entire steam distribution system was mapped. As discussed in Chapter 2, Figure 1 shows the distribution map with the general location of building areas on the distribution system. To run the program, the system had to be modeled as six building areas serviced by two plants. Each plant was configured to provide steam to three building areas.

SHDP is designed to estimate the total heat load to the heating plant with a breakdown of the distribution losses. This requires entering distribution line nodes, line diameters and lengths, CHP supply pressure, and individual building loads. Nodes are locations of pipe size changes, pressure reducing valves, and thermal loads (typically buildings). Pipe diameters and lengths were obtained from blueprints of the distribution system. As described in the previous section, the thermal loads for each building were estimated using the HEATLOAD program. Table 7 lists the basic assumptions that were made in creating the distribution model for Fort Dix.

The SHDP model was run using unconstrained pressure throughout the system to determine if adequate pressure is available to each building for the design heating day temperature of 5 °F. For the north half of the system, the results indicated that, if the boiler outlet pressure at CHP 5426 is 110 psi, Building 5441 would experience the lowest pressure in the system at 83.7 psi. For the south half of the system, the results indicate that, if the boiler outlet pressure at CHP 5881 is 110 psi, Building 5707 would experience the lowest pressure at 105.6 psi. This analysis indicates that the distribution system can provide the required pressure at all buildings. Appendix A lists the SHDP output of the unconstrained pressures and steam flows for each building.

Table 7. SHDP model assumptions.

Assumption	Value
Pipe environment temperature	53 °F
Load condensate temperature	150 °F
Steam trap leakage rate	5%
Fraction of load condensate returned	100%
Fraction of pipe condensate returned	70%

Heating Load vs. Thermal Model

Thermal production for building heating correlates well to outside temperature or HDD. As mentioned above, HEATLOAD is a first-order model for predicting thermal loads as a function of HDD. Combining the HEATLOAD predictions with the line and trap losses calculated from SHDP produces a linear expression for the steam distribution to calculate an overall system model.

The thermal model appears to contain the data range of the actual system performance. When superimposing the thermal model on the thermal production data, all of the points fall on or below the model curve (Figure 12). Statistically, it is expected that some of the data points would occur above the model equation line. However, the shortfall of the actual steam consumption from the expected steam consumption may be due to the large number of vacant or only marginally occupied buildings. As mentioned earlier, the system may have to meet much higher loads than normally experienced if there is a mobilization and more buildings become fully occupied. Under fully occupied conditions, the thermal model should be a better predictor of system performance.

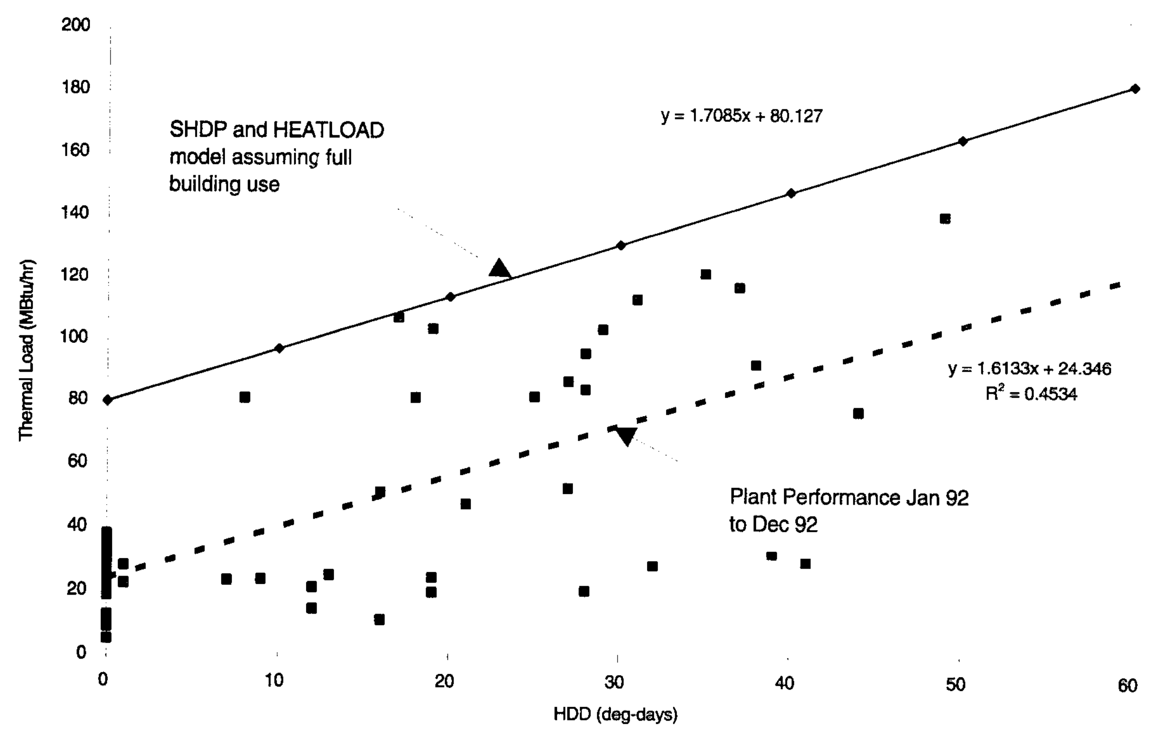

Figure 12. Thermal model versus HDD.

4 Electrical Power Consumption

Electrical Costs

Electrical power is supplied to Fort Dix by the Jersey Central Power and Light Company (JCPL). Table 8 gives the basic rate schedule. Of these costs, the energy-use charges and the demand charge are the most significant. Figure 13 shows the magnitude of the major electric charges for fiscal year 1992 (FY92) from Fort Dix's electric bills. The demand charge accounts for about 21 percent of the annual electric charges, the off-peak use charges accounts for 40 percent, and on-peak use accounts for about 38 percent. Line, transformer, and energy adjustments account for 1 percent.

The demand charge for FY92 averaged \$121,000 per month in the summer and \$81,000 per month in the winter, or \$94,479 per month for the year. The average demand cost was \$8.69/kW based on an average peak demand of 10,771 kW. The total cost of electricity was \$5.2 million for 67.6 million kWh, or \$0.0767/kWh (\$22.48/MBtu).

The electricity charges peak significantly during the summer months due to a combination of higher demands, higher base load, and high demand charges (Figures 14 and 15). There is also an increase in winter costs due to higher base load. Appendix B lists the Fort Dix electrical load, electrical demand, and electrical charges.

Table 8. Electric rate schedule calendar year 1992.

Charge Types	Cost (\$)	Charge Acceptability
Off-peak	0.05158 per KWHr	
On-peak	0.07330 per KWHr	
Demand summer	9.22 per KW	June – Sept
Demand winter	8.31 per KW	Oct – May
Transformer charge	2409.78 per month	Based on previous highest demand
Interconnect line charge	428.70 per month	
Customer charge	383.99 per month	
Excess KVA charge	0.54 per KVA	Before May 1992
KVAR charge	0.19 per KVAR	After May 1992

Note: Energy cost credits of \$0.00105 to \$0.003654 per KWHr applied to some months billing in 1992. Current rate structure contains only customer charge, KVAR charge, 15 minute peak demand, on-peak KWHr and off-peak KWHr.

Electric Load vs. CDD Model

The comparison of electric load with Cooling Degree-Day (CDD) yields some insight on the nature of electrical usage. Since only monthly data was available from JCPL, the correlations will not be as strong since 30 days of data is averaged together and compared with the charge for a 15-minute maximum peak demand event. The electrical usage in a month correlates poorly with the monthly CDD (Figure 16). The strongest correlation is between the peak demand (KW) and the monthly CDD and even that is weak at R=0.29 (R > 0.9 is a strong correlation, cf. Figure 17). Analysis of daily metering data may quantify the savings by reducing peak demand during the cooling season. The monthly data available shows months with zero CDD have loads just as high or higher than months with 300 CDD.

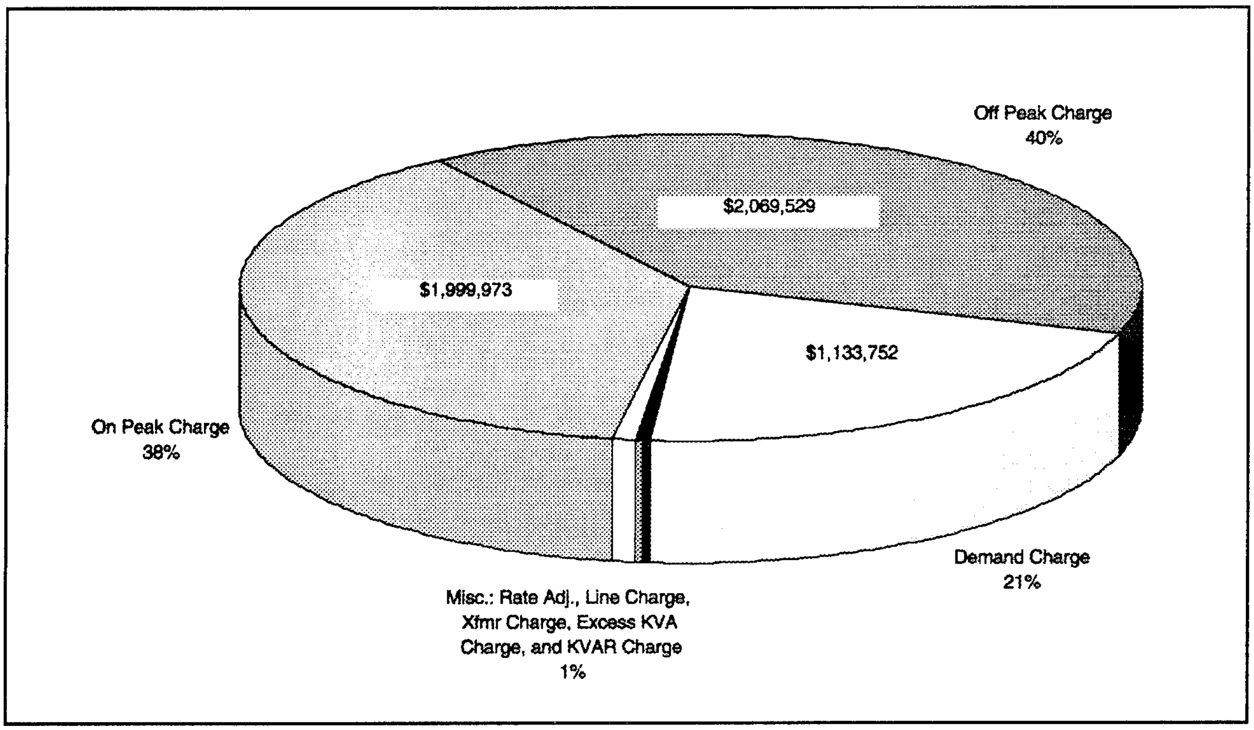

Figure 13. Annual electrical charges, CY92.

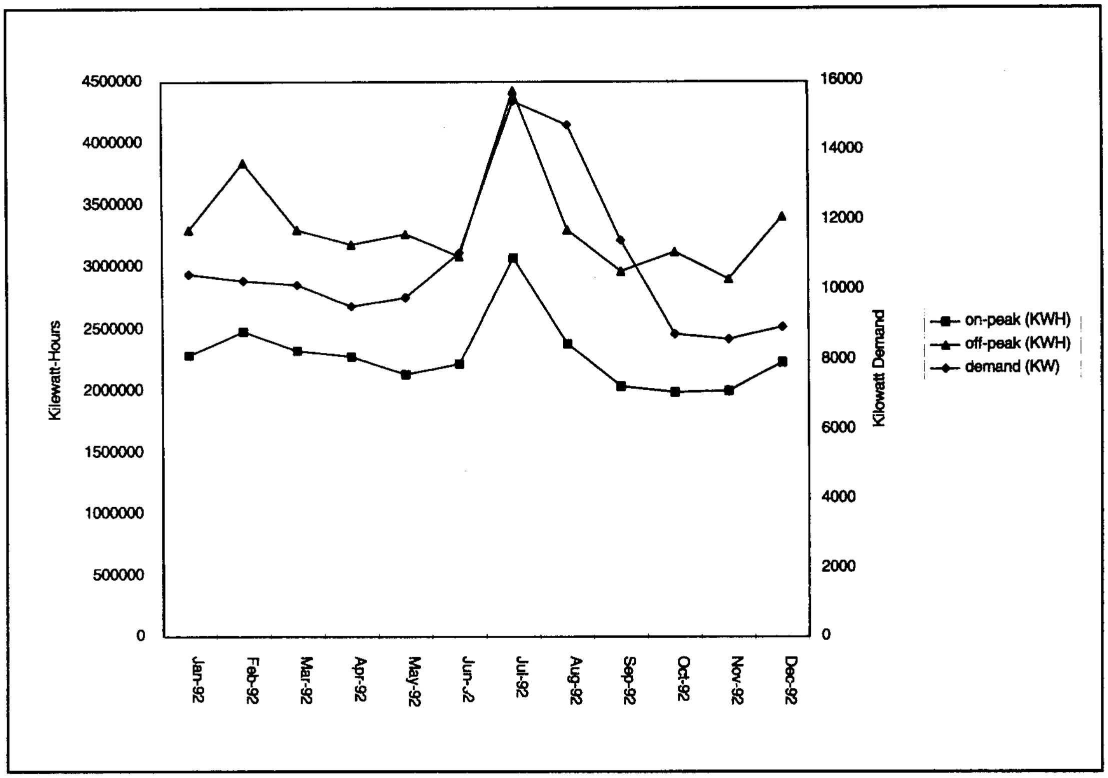

Figure 14. Electrical loads, CY92.

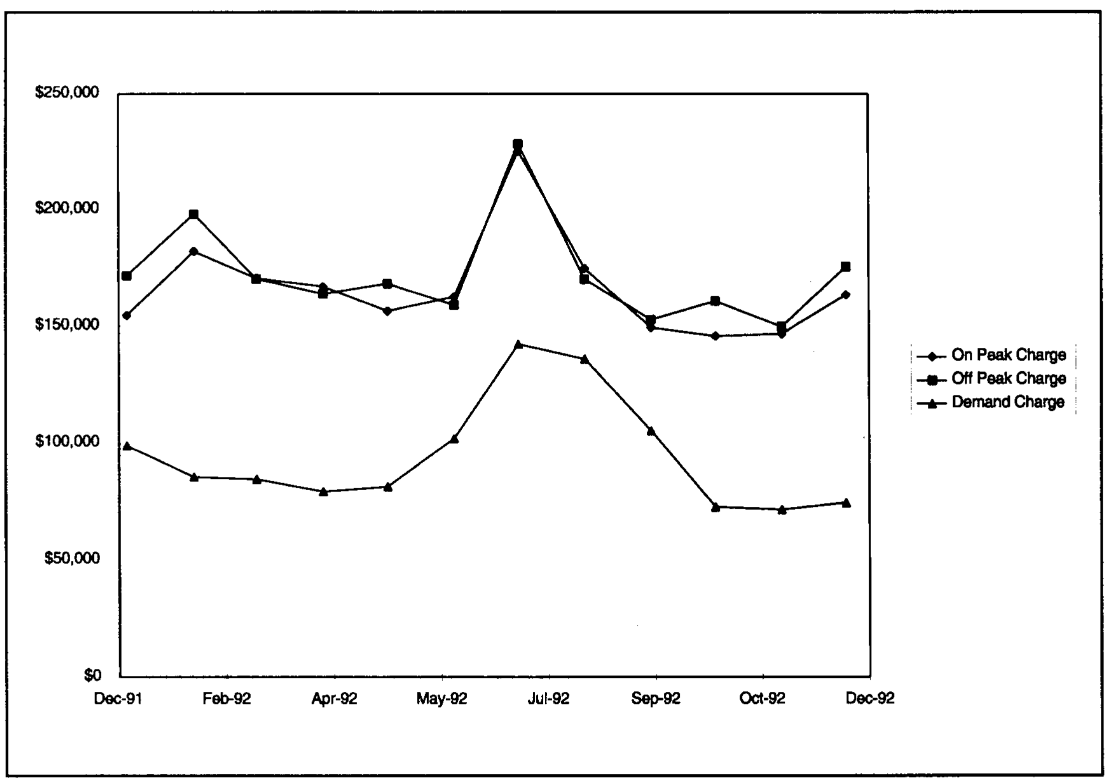

Figure 15. Electrical charges, CY92.

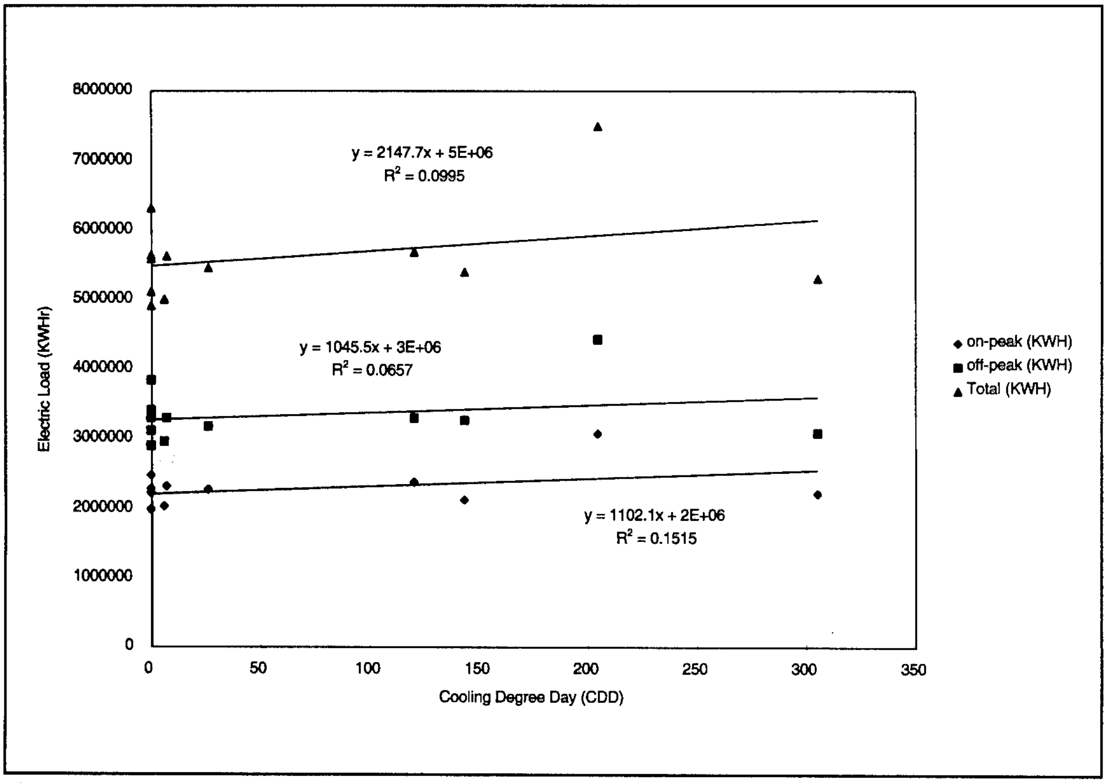

Figure 16. Electrical load vs. CDD, CY92.

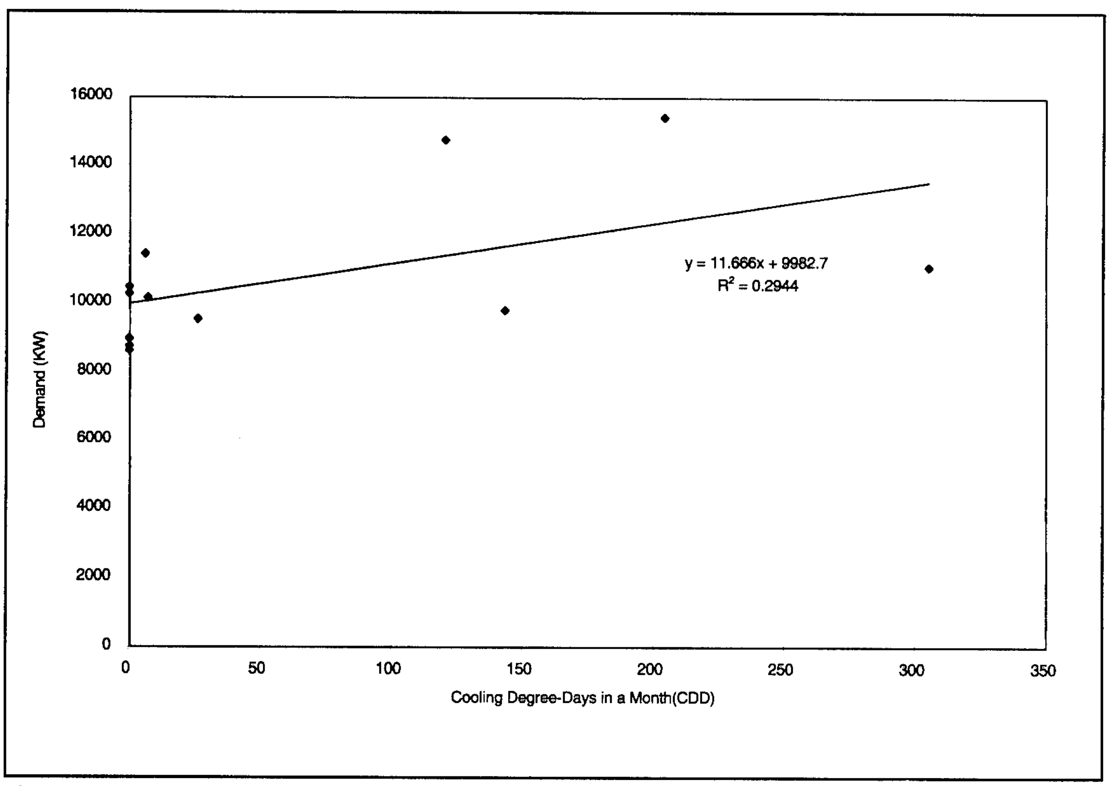

Figure 17. Maximum demand vs. CDD, CY92.

5 Projected Energy Consumption

A significant portion of the installation is occupied by Army Reserves, Naval Reserves, U.S. Air Force commands, and other federal and state agencies. No information was collected on the long-range plans of these tenant commands. However, experience from the recent mobilizations indicates that Fort Dix must be prepared to rapidly increase thermal production as occupancy levels increase. Because of the uncertain nature of these changes, energy consumption projections will be based on normal weather data and design temperatures only. The effect will be to somewhat over-estimate heating loads and underestimate electrical loads. The heating plant must be designed to provide adequate turndown for the tentative reductions in heating load.

Table 9 shows Normal HDD, monthly heating load estimates, and design day estimate using the steam log data, 60-percent efficiency fuel data, and HEATLOAD/SHDP. The linear model of heating load and HDD developed from the 1992 data was modified using the Normal HDD to estimate the average monthly heating loads. Figure 18 compares the heating loads projected by the various methods. As discussed previously, HEATLOAD provides a reasonable estimate of full building occupancy demand. However, it can overestimate in reduced facility utilization situations such as

Table 9. Normal HDD and thermal production projections.

Month	HDD (Monthly)	CDD (Monthly)	Total Thermal Production (lb/hr) minus laundry	Total Thermal Production (MBTU/hr) minus laundry	HEATLOAD and SHDP Model (MBTU/hr)	No. 6 Oil Use (Logged Data) (MBTU/hr)	Thermal Production (60% ave logged eff) (MBTU/hr)
Jan	1011.2	0.0	76,461	76.973	135.859	127.385	76.516
Feb	859.6	0.0	72,950	73.434	132.112	121.638	73.064
Mar	670.7	1.8	58,873	59.249	117.089	98.600	59.226
Apr	380.1	11.8	44,521	44.787	101.774	75.113	45.118
May	125.6	66.6	30,724	30.884	87.051	52.534	31.556
Jun	14.8	221.6	25,026	25.142	80.970	43.209	25.954
Jul	0.7	353.9	24,270	24.381	80.164	41.972	25.212
Aug	2.7	320.7	24,374	24.485	80.274	42.141	25.313
Sep	45.4	155.9	26,657	26.786	82.711	45.878	27.558
Oct	241.1	26.7	36,686	36.892	93.413	62.291	37.416
Nov	498.3	3.2	50,827	51.141	108.503	85.433	51.317
Dec	847.8	0.1	68,022	68.469	126.854	113.574	68.221

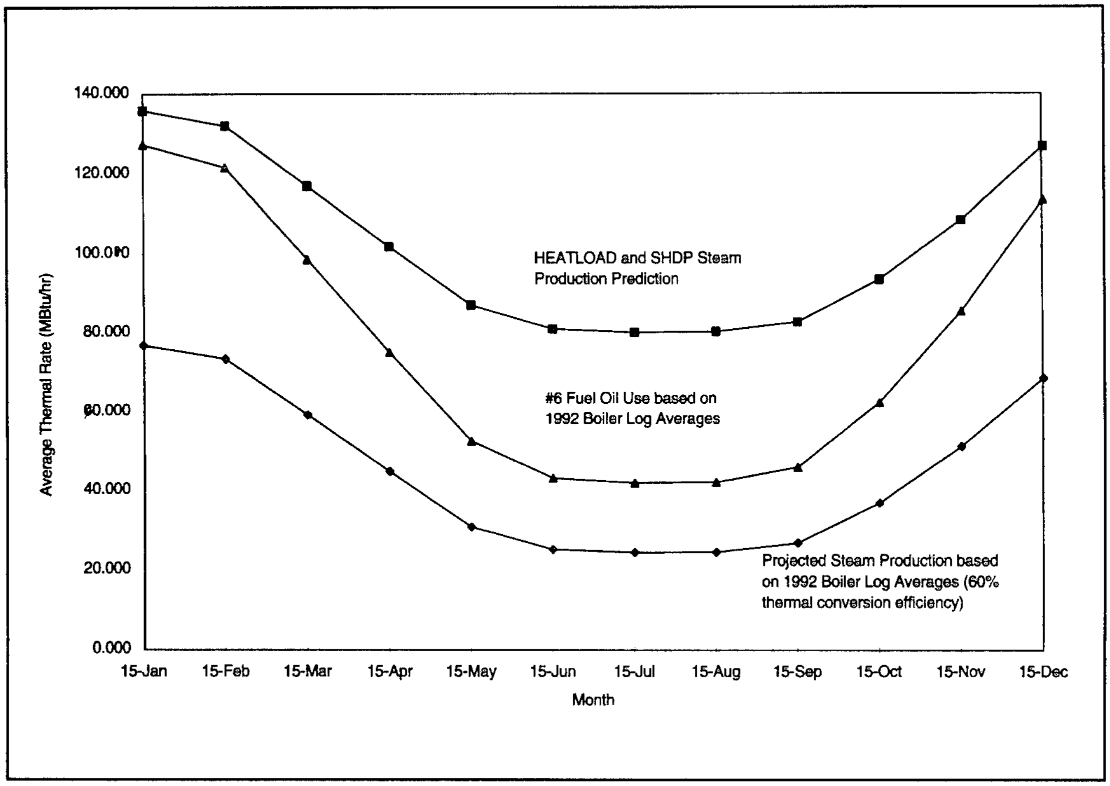

Figure 18. Projected thermal loads for normal HDD year.

experienced at Fort Dix. The logged data and operational tests indicate an approximate 60-percent fuel-to-steam conversion. It is reasonable to achieve a 76-percent conversion in most central energy plants. Improvements suggested in the following chapter may yield savings of up to $600,000 per year. Appendix C fully tabulates the plant log and energy model projections.

Table 10 shows the Normal CDD, monthly electrical load, and cost estimates using linear regressions of CY92. The 1994 rate structure was used to calculate the cost estimates. Figure 19 contains the breakdown of the annual electrical costs.

Table 10. Normal CDD and electrical load projections.

Month	CDD (Monthly)	Off-Peak Load (kWhr)	On-Peak Load (kWhr)	Demand (kW)	Off-Peak Cost	On-Peak Cost	Demand Charge	Total Elect. Cost
Jan	0.0	3300000	2200000	9982.7	$206,448	$159,412	$82,956	$448,816
Feb	0.0	3300000	2200000	9982.7	$206,448	$159,412	$82,956	$448,816
Mar	1.8	3301882	2201882	10003.7	$206,566	$159,548	$83,131	$449,245
Apr	11.8	3312337	2212337	10120.36	$207,220	$160,306	$84,100	$451,626
May	66.6	3369595	2269595	10759.27	$210,802	$164,455	$99,200	$474,457
Jun	221.6	3531683	2431683	12567.89	$220,942	$176,200	$115,876	$513,018
Jul	353.9	3669968	2569968	14110.91	$229,593	$186,220	$130,103	$545,916
Aug	320.7	3635257	2535257	13723.6	$227,422	$183,705	$126,532	$537,658
Sep	155.9	3463028	2363028	11801.82	$216,647	$171,225	$108,813	$496,685
Oct	26.7	3327915	2227915	10294.18	$208,194	$161,435	$85,545	$455,174
Nov	3.2	3303346	2203346	10020.03	$206,657	$159,654	$83,266	$449,578
Dec	0.1	3300105	2200105	9983.867	$206,455	$159,420	$82,966	$448,840

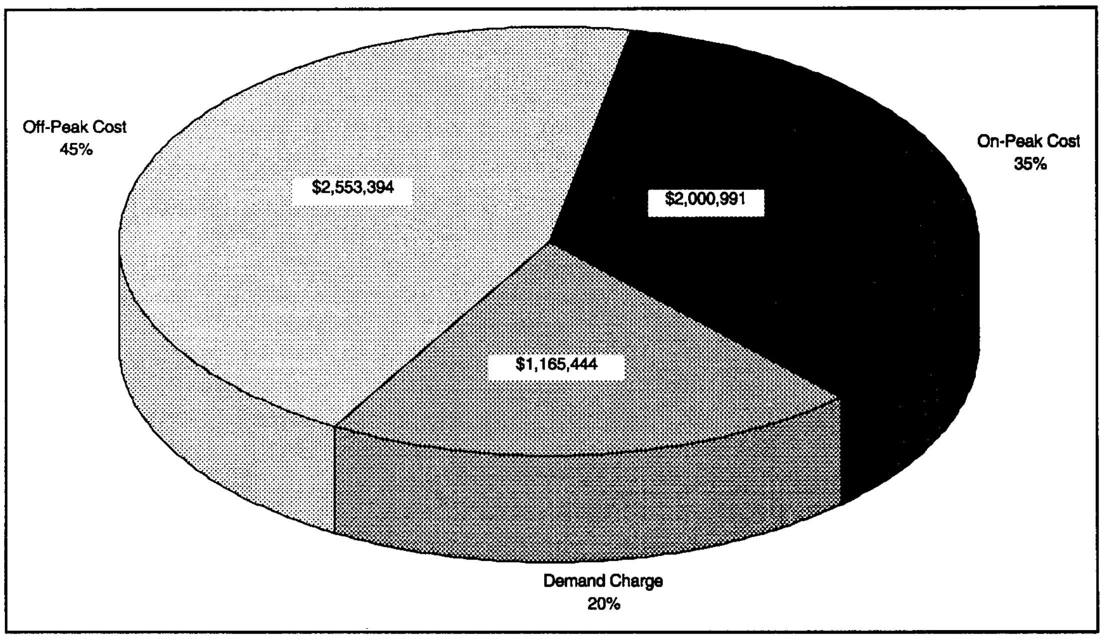

Figure 19. Projected annual electrical charges for normal cooling degree-day year.

6 Energy Plant Repairs and Modifications

USACERL and Schmidt Associates Inc. (SAI) visited CHPs 5426, 5881, and 5324 at Fort Dix on 20 September 1994 to develop short-range work items to improve the efficiency of the central energy system. Appendix D shows the short list based on that site visit. In general, the list focused on improving heat transfer in the boilers in CHP 5426, improving plant instrumentation, and upgrading the condition of auxiliary systems (feedwater, reduced pressure steam). After review of comments from the 20 September visit, USACERL and SAI performed an inspection and analysis of the boilers in CHP 5426 on 14-16 November 1994. The purpose of the visit was to specifically identify the causes of the poor heat transfer and thermal efficiency of the Erie City Iron Works boilers in CHP 5426 (Table 11).

To more accurately assess the condition of the boilers in CHP 5426, USACERL and SAI installed portable instrumentation on the boilers to verify in-plant performance recorders. Dual thermocouples and gas analyzers were used to take data on both the right and left sides of the furnace. The site visit consisted of:

1. *Operational Tests of Boilers No. 1 and No. 3*—O_2, CO, CO_2, NOx, SOx, furnace pressure, and boiler outlet temperatures were measured under low, medium, and high fire conditions on both the left and right sides of the boilers.

2. *Internal Inspection of Boiler No. 2*—Visual inspection was done of the furnace, of the UT thickness of 22 tubes 4-½ feet off of the furnace floor, of furnace and generating tube baffle, of left water wall header (watersides), and of water wall tube inlet (waterside).

The visit confirmed some of the suspected causes of poor heat transfer in the boilers in CHP 5426. Appendix E lists the inspection findings. SAI also separately submitted

Table 11. Boilers installed in CHP 5426.

Bldg.	Boiler Ser. No.	Boiler Cap. (lb/hr)	Manuf.	Fuel	Year Built	Press. (psig)	Heating Surface (sq ft)	Tube Dia.	No. of Tubes	BHP
5426	NB-14488	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	NB-14489	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	NB-14490	50,000	Erie City Iron	#6 Oil	1953	160	7660	2.5	747	1535
5426	—	50,000	Keeler	#6 Oil	—	—	—	—	—	—

a full technical evaluation of the condition of the boilers (Appendix F). A consolidated work item lists recommendations to improve the thermal efficiency of CHP 5426 (Appendix G). The major items for CHP 5426 from Appendix G are:

- Improve heat transfer of boilers No. 1, No. 2, and No. 3
  - repair ID fan controls
  - acid wash fireside of boiler tubes
  - acid clean waterside of boiler tubes
  - repair refractory and repair tube ties

- Improve boiler auxiliaries
  - verify soot blowers properly sized for reduced pressure operation
  - inspect and repair de-aerating tank internals
  - repair boiler instrumentation
  - repair/replace gas burner ring assemblies

- Other items to improve industrial hygiene/ergonomics
  - move feedwater regulating valves to operating floor
  - upgrade platforms and ladders.

7 Distribution System Alternatives

Three alternatives were examined for the thermal distribution system, one of which was simply to maintain the status quo. A life-cycle analysis was conducted for each option using the Life-Cycle Cost in Design (LCCID) computer program. LCCID incorporates the economic criteria and guidance of DOD and National Institute of Standards and Technology (NIST) documents. Specifically, the life-cycle cost is to be calculated for energy projects over a 25-year life using a 3.1 percent discount factor for nonfuel costs and NIST Handbook 135 tabulated discount factors for fuel costs. The thermal and fluid performance of all three options were modeled with the HEATMAP program. This software uses the commercial heating distribution design software LICHEAT to model steam and hot water systems. HEATMAP uses LICHEAT to create economic and thermal analyses that comply with Federal life-cycle cost analysis regulations. HEATMAP also considers labor and material operations and maintenance (O&M) costs. The entire distribution system was broken into two separate systems with one plant each located in the steam loops. HEATMAP is still in development, but a full analysis was run on a simplified distribution system to model Fort Dix as part of the beta test program.

The first option was to consider replacing the present steam distribution system "in kind." Although major portions of the present distribution system may be salvageable, this calculation is appropriate as a baseline comparison with the other new hot-water options. Additionally, the very small sampling of the condition of the present system indicated that a major capital investment may be required to achieve 25 more years of efficient steam distribution. HEATMAP looked at two steam production plant options to bracket the actual plant condition. The first LCC assumed the steam plant to be in near-new condition (not needing any capital investment). The second LCC comparison assumed the steam plant would be constructed in year one. Table 12 summarizes the HEATMAP analysis output. Appendix H gives the complete list of the HEATMAP/LCCID output for the steam options.

The second option considered was low temperature hot water (225 °F). Table 13 summarizes the HEATMAP analysis output. This option will allow removal of steam to hot water converters and greatly reduce line losses. However, the reduced thermal density of the hot water when compared to steam will require installating slightly larger distribution pipes to meet the maximum load. However, the pipe sizes

calculated by HEATMAP are still less than the installed steam pipe sizes. Appendix I gives the complete HEATMAP/LCCID output for the low temperature option. The 25- year life-cycle cost of low temperature hot water is about 5 percent less than the high temperature option.

The third option considered was the high temperature hot water (325 °F). Table 14 summarizes the HEATMAP analysis output. This option will allow smaller pipe sizes and the removal of the steam-to-hot-water converters, but will require that high-temperature-to-low temperature heat exchangers be installed. Appendix J gives the complete HEATMAP output for the high temperature option.

Table 15 lists each category of the life-cycle costs of each option for the thermal distribution system. In general, the 25-year life-cycle cost of a new steam distribution system (newly built plant) is about 26 percent more than the low-temperature hot water option and 21 percent more than the high-temperature hot water option. Although the capital cost of a boiler is less than a hot water generator, the increased line losses, increased distribution installation cost, and expense of maintaining steam-to-hot-water converters is greater. Additionally, steam systems require greater O&M resources to service the traps and converters, and to replace condensate piping. Of particular interest is that the life-

Table 12. HEATMAP output summary for 50 HDD for steam distribution.

Output Category	Quantity
Maximum pressure (psig)	115.0 at node N026
Maximum delta p (psig)	40.4 at node N047
Minimum delta p (psig)	20.2 at node N036
Total energy produced	146.4 MBtu/hr
Total energy consumed	106.3 MBtu/hr
Thermal distribution losses	22.3 MBtu/hr
Failed trap losses	17.8 MBtu/hr
Pipe leakage losses	0.0 MBtu/hr
Total losses	40.1 MBtu/hr
Losses as % of production	27.4%
Total flow from plant(s)	117493 lb/hr
Total flow through consumers	102510 lb/hr
Flow losses (pipes)	0 lb/hr
Flow losses (traps)	14983 lb/hr
Total flow losses	14983 lb/hr
Flow losses as % of total	13 %

Table 13. HEATMAP output summary for 50 HDD for low temperature hot water distribution.

Output Category	Quantity
Maximum temperature (°F)	225.0 at node N026
Maximum pressure (psig)	75.0 at node N026
Maximum delta p (psig)	25.8 at node N046
Minimum delta p (psig)	5.7 at node N028
Total energy produced	109.0 MBtu/hr
Total energy consumed	106.3 MBtu/hr
Thermal distribution losses	2.7 MBtu/hr
Losses as % of production	2.4%

Table 14. HEATMAP output summary for 50 HDD for high/medium temperature hot water distribution.

Output Category	Quantity
Maximum temperature (°F)	325.0 at node N026
Maximum pressure (psig)	150.0 at node N026
Maximum delta p (psig)	26.1 at node N026
Minimum delta p (psig)	4.2 at node N028
Total energy produced	111.6 MBtu/hr
Total energy consumed	106.3 MBtu/hr
Thermal distribution losses	5.3 MBtu/hr
Losses as % of production	4.7%

cycle cost per MBTU for operating a new steam distribution system is $22.77/MBTU steam delivered (average) as compared to $48.45/MBTU steam delivered (average) based on the current steam system performance (60 percent thermal efficiency). Although the life-cycle steam cost at the boiler outlet currently is only $21.38/MBTU, the line losses will force the provider to charge the end user $48.45/MBTU to adequately fund the current steam plant and distribution system operation. However, if the current plant efficiency is increased to 82 percent, the trap losses are reduced to 5 percent (for a total line and trap loss of 27 percent), and no charge is made for life-cycle plant capital costs, then the charges drop to $16.53/MBTU at the plant outlet and $20.67/MBTU at the point of usage.

These figures bracket what sort of service charge should be made to the tenant commands to fund the heating plant operation on a reimbursable basis. With the significant number of tenant commands at Fort Dix, it may be appropriate to review the steam utility rates so the Army can avoid subsidizing the operation of other agencies' operations. Additionally, the relatively low thermal usage density at Fort Dix may make other distributed energy options more desirable. However, before initiating a rate change, the thermal performance of production and distribution system should be improved and the steam metering accuracy should be upgraded.

Table 16 summarizes the calculations of the fuel cost and energy usage savings from switching to hot water. The actual savings may be much greater at full facility occupancy since the hot water options are being benchmarked to the new steam plant. However, if the trend of underutilizing buildings continues, the actual variable cost savings (fuel, repairs) will be less than the projected savings of switching to the hot water options. The reduced fuel savings will increase the discounted payback period (DPP) and decrease the savings-to-investment ratio (SIR). As discussed in Chapter 3, the current steam distribution system experiences a constant 30,000 lb/hr line and trap loss. Subtracting this load from the steam demand profile (Figure 20) shows that, for most of 1992, the steam usage may only be 45 to 55 percent of that expected at full occupancy. The trap and line losses will vary as a function of demand (system steam flow) as well as temperature. For full occupancy, SHDP predicts a 57,000 MBTU/hr trap and line loss to meet a 23,000 MBTU/hr tenant demand on a zero HDD (65 °F) day. SHDP forecasts the total steam loss for a zero HDD of 66,000 MBTU/hr while meeting a demand of 116,000 MBTU/hr. These comparisons indicate that LCCID savings calculations may need adjustment for building occupancy trends.

Table 15. Life-cycle cost summary for thermal distribution options at Fort Dix.

Option	Steam (No Plant Investment)	Steam (New Plant)	Low Temp Hot Water	High Temp Hot Water	Log Estimate Normal HDD Year (Current 60% Eff)	Log Estimate Normal HDD Year (Current 76% Eff)	HEATMAP/SHDP Normal HDD Year (Current 76% Eff)
Ave. Annual Energy Use (MBtu Fuel)	602,295	602,295	491,537	500,747	662,849	523,886	1,177,664
Ave. Annual Steam HW Production (MBtu Steam/yr)	493,882	493,882	403,060	410,613	397,709	398,153	895,025
Ave. Annual Energy Use (MBtu Steam/yr) HEATLOAD est.	395,015	395,015	395,015	395,015			395,015
Extrapolated Energy Used in Bldgs (MBtu Steam/yr)					175,527	175,723	
25 Year Life Cycle Costs							
Year 1 Capital Investment	$0	$14,460,230	$9,684,211	$13,932,710	$0	$0	$0
O&M Cost	$81,868,450	$81,844,300	$63,502,990	$64,692,820	$81,868,450	$81,868,450	$81,868,450
Energy Cost ($4.56/Mbtu)	$58,680,940	$58,680,940	$47,889,920	$48,787,240	$64,580,629	$51,041,640	$114,738,505
LCC Energy Cost ($5.32/Mbtu)	$68,461,097	$68,461,097	$55,871,573	$56,918,447	$75,344,067	$59,548,580	$133,861,589
Plant Electrical Cost ($22.58/Mbtu)	$1,717,037	$1,717,037	$2,033,487	$2,067,812	$1,717,037	$1,717,037	$1,717,037
Total ($4.56/MBtu)	$142,266,427	$156,702,507	$123,110,608	$129,480,582	$148,166,116	$134,627,127	$198,323,992
Total ($5.32/MBtu)	$152,046,584	$166,482,664	$131,092,261	$137,611,789	$158,929,554	$143,134,067	$217,447,076
Uniform Annual Cost ($)							
($4.56/MBtu Fuel)	$8,166,093	$8,994,724	$7,066,549	$7,432,185	$8,504,735	$7,727,597	$11,383,797
($5.32/MBtu Fuel)	$8,727,474	$9,556,105	$7,524,696	$7,898,917	$9,122,556	$8,215,895	$12,481,462
Steam HW Cost at Plant ($/MBtu)							
($4.56/MBtu Fuel)	$16.53	$18.21	$17.53	$18.10	$21.38	$19.41	$12.72
($5.32/MBtu Fuel)	$17.67	$19.35	$18.67	$19.24	$22.94	$20.64	$13.95
Steam HW Cost at Bldg ($/MBtu)							
($4.56/MBtu Fuel)	$20.67	$22.77	$17.89	$18.81	$48.45	$43.98	$28.82
($5.32/MBtu Fuel)	$22.09	$24.19	$19.05	$20.00	$51.97	$46.75	$31.60

Table 16. LCCID analysis summary for thermal distribution options at Fort Dix.

Alternative	Investment	Energy	O&M	Total	SIR	DPP
Steam (old plant)	$0	$60,397,980	$81,868,450	$142,266,430	N/A	N/A
Steam (new plant)	$14,460,232	$60,397,980	$81,844,300	$156,702,512	N/A	N/A
Low Temp Hot Water	$9,959,053	$49,923,404	$63,502,990	$123,385,447	N/A	N/A
High Temp Hot Water	$14,328,130	$50,855,056	$64,692,820	$129,876,006	N/A	N/A
Incremental Costs						
Steam (old plant)	$0	$0	$0	$0	N/A	N/A
Steam (new plant)	$14,460,232	$0	($24,150)	$14,436,082	0.00167	>99
Low Temp Hot Water	$9,959,053	($10,474,576)	($18,365,460)	($18,880,983)	2.895861	7
High Temp Hot Water	$14,328,130	($9,542,924)	($17,175,630)	($12,390,424)	1.864762	12

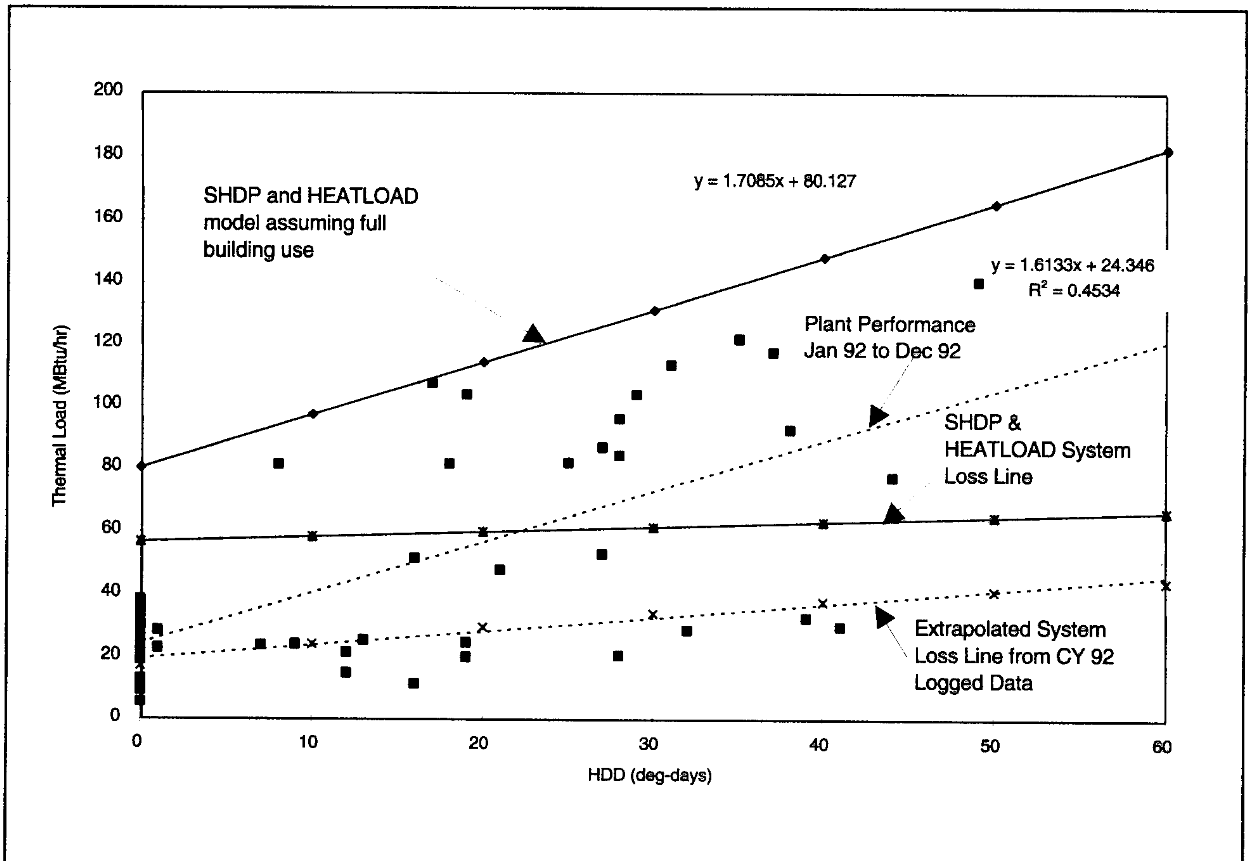

Figure 20. Steam demand profile with line and trap loss estimates.

8 Air Quality Regulations

Air quality regulations are the most significant environmental regulations that will affect the operations of the central energy plants. The Clean Air Act Amendments (CAAA) of 1990 are putting tighter constraints on emissions from most industrial sources, particularly combustion sources.

Federal Regulatory Issues

Burlington county has been designated as a nonattainment for ozone (O_3) in the New Source Review (NSR). Camden county to the west is in nonattainment of ozone (O_3) and carbon monoxide (CO). The entire state of New Jersey is in attainment of nitrous oxides (NOx), particulate matter, and lead. New Jersey is in USEPA region II (offices in New York City) and also part of the Northeast Transport Region (NTR), which invokes more stringent standards. The NTR lowers the definition of major Volatile Organic Compound (VOC) source to 50 tons per year and a NOx source to 100 tons per year even in areas with local ozone attainment.

State and Local Regulatory Requirements

Permits to construct must be obtained from the State of New Jersey. Significant help is available to firms and agencies through the use of a "one-stop" construction permit identification program. On completion of the comprehensive "one-stop" form, the applicant will receive, within 15 working days, a notification identifying all required state construction permits, the necessary forms, and an offer of the services of a "permit expediter" from the Office of Business Advocacy. The details of the program can be obtained from:

The Department of Commerce and Economic Development
Office of Business Advocacy
20 West State Street, CN 823
Trenton, NJ 08625
tel: 609/292-0700

The NOx requirements will change on 15 May 1995. Permit applications were due 23 April 1994 from sources in operation prior to 23 January 1994. Table 17 summarizes the New Jersey limits for nonutility boilers.

Summary

Air pollution regulations related to NOx production will impact the operation of the boilers at full capacity. If the boilers are to be rated to operate at greater than 50 MBTU/hr heat input, the burner and furnace design will have to meet more stringent requirements.

Table 17. New Jersey nitrogen oxide limits for non-utility boiler

Fuel/Boiler Type	Face firing 50-100 MBTU Heat Input (lb/MBTU)	Face Firing >100 MBTU Heat Input (lb/MBTU)
Coal – wet bottom	1.0	1.0
Coal – dry bottom	0.43	0.45
No. 2 fuel oil	0.12	N/A
Other liquid fuels	0.3	N/A
All oil	N/A	0.28
Oil and gas (dual)	N/A	0.28
Gas	0.1	0.2 (gas exclusively)

Note: Nonutility boilers with heat input greater than 250 MBtu/hr must be equipped with continuous emission monitoring systems (CEMS).

9 Conclusions

This study assessed current capabilities of the thermal production plant and estimated the economic feasibility of using two hot water distribution systems in comparison with the two steam distribution options that bracket the current production situation. It is concluded that significant savings—of over $600,000 per year—may be realized by improving the thermal performance of the boilers in CHP 5426.

The low-temperature hot water distribution system is the lowest life-cycle cost thermal distribution option even when compared with a baseline condition of not making any capital investments in the steam plant. Based on the HEATMAP/LCCID analysis, a new low temperature hot water system will have a saving-to-investment ration of 2.9 and a discounted payback period (DPP) of 7 years.

However, due to the low thermal usage density at Fort Dix, the cost of the hot water at the end user will be $17.89/MBTU (No. 6 oil @ $0.67/gal) or $19.05/MBTU (gas @ $0.5632/therm). These costs are significantly higher than charges assessed by urban or campus steam distributors. More typical steam costs are $4 to $7/MBTU. Unless fuel redundancy requirements dictate otherwise, distributed energy usage options may be less expensive than central energy plants.

In summary, large savings may be realized using the current equipment, repaired to improve efficiency. If a new central energy infrastructure is to be built or major capital investment is needed for the current plant, low temperature hot water is the lowest life-cycle central plant option. Due to the low thermal usage density, distributed energy alternatives should also be considered.

Appendix A: SHDP Output for Unconstrained Pressures and Flows

The following data output is for the flows and loads at 5 °F at Fort Dix, NJ.

08/30/94 11:46:52
a05a

Ft. Dix Loop A
CHP 5881 loads

SOLUTION COMPLETED IN 9 ITERATIONS
SOME NODES MAY NOT BE BALANCED

*** PROBLEM SUMMARY ***
56 NODES IN THE SYSTEM
55 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
5 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
55 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
HRI	110.04?	10000.0	-83.8	.0	26442.9	344.2	-13.00
5881	110.00	39482.9?	-280.7	.0	88585.0	344.2	12.52
A1	109.84?	-30356.3	-885.6	3553162.0	195565.4	344.1	1.23
A2	108.83?	.0	-903.5	.0	199112.6	343.4	-.18
A3	108.65?	.0	-40.2	.0	8853.1	343.3	-.04
A4	108.12?	.0	-22.4	.0	4937.8	343.0	.00
A5	107.98?	.0	-12.7	.0	2790.6	342.9	-.02
A6	107.93?	.0	-292.3	.0	64303.7	342.9	-.13
A7	107.47?	.0	-134.7	.0	29594.9	342.6	.47
A8	107.43?	.0	-98.8	.0	21700.6	342.6	-.26
A9	107.18?	.0	-150.3	.0	33001.3	342.4	-.19
A10	106.97?	.0	-135.5	.0	29744.9	342.3	.35
A11	106.84?	.0	-97.3	.0	21347.5	342.2	-.66
A12	106.80?	.0	-122.6	.0	26910.8	342.2	.88
A13	106.63?	.0	-135.5	.0	29733.8	342.1	.33

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
A14	106.58?	.0	-141.5	.0	31047.1	342.0	-.51
A15	106.47?	.0	-224.1	.0	49151.9	342.0	.13
A16	106.19?	.0	-71.2	.0	15599.3	341.8	.01
A17	106.10?	.0	-39.9	.0	8751.1	341.8	.00
A18	106.17?	.0	-119.6	.0	26210.8	341.8	.05
A19	105.90?	.0	-131.4	.0	28783.6	341.6	.05
A20	105.71?	.0	-96.0	.0	21010.7	341.5	.07
A21	105.67?	.0	-68.6	.0	15009.0	341.5	-.02
A22	105.60?	.0	-126.1	.0	27609.7	341.4	.31
A23	105.53?	.0	-118.1	.0	25848.1	341.4	-.61
A24	105.52?	.0	-174.1	.0	38096.6	341.4	.55
5922	108.61?	-148.0	-2.9	17323.2	645.9	343.3	-.01
5923	108.09?	-148.0	-2.9	17323.2	644.3	343.0	-.01
5924	107.95?	-148.0	-2.9	17323.2	643.9	342.9	.00
5917	107.83?	-278.0	-2.9	32539.5	643.1	342.8	-.02
5918	107.19?	-139.0	-22.4	16269.8	4919.7	342.4	-.04
5910	107.39?	-919.0	-123.5	107567.6	27126.6	342.6	-.08
5904	107.35?	-114.0	-103.0	13343.5	22626.1	342.5	-.08
5911	101.94?	-919.0	-14.1	107567.6	3060.5	339.1	-.02
5912	106.87?	-919.0	-16.3	107567.6	3582.0	342.2	-.07
5919	106.44?	-139.0	-29.2	16269.8	6394.5	342.0	-.04
5913	106.75?	-919.0	-123.2	107567.6	27044.3	342.2	-.06
5905	106.71?	-114.0	-102.8	13343.5	22557.5	342.1	-.08
5951	106.53?	-919.0	-16.3	107567.6	3576.1	342.0	-.06
5954	106.02?	-278.0	-14.6	32539.5	3189.1	341.7	-.03
5953	105.92?	-303.0	-14.5	35465.7	3187.2	341.6	-.03
5955	106.05?	-159.0	-9.7	18610.7	2126.9	341.7	-.02
5956	106.05?	-89.0	-9.7	10417.3	2127.0	341.7	-.03
5957	106.04?	-211.0	-2.9	24697.3	637.9	341.7	-.03
5950	104.76?	-195.0	-58.1	22824.5	12698.2	340.9	-.04
5958	105.69?	-278.0	-12.6	32539.5	2759.3	341.5	-.03
5952	105.75?	-919.0	-24.4	107567.6	5344.2	341.5	-.08
5994	105.31?	-139.0	-29.1	16269.8	6359.6	341.3	-.04
5989	105.63?	-919.0	-122.9	107567.6	26897.4	341.5	-.04
5985	105.58?	-114.0	-102.5	13343.5	22435.0	341.4	-.08
5990	105.45?	-919.0	-24.4	107567.6	5336.4	341.3	-.06
5991	105.38?	-919.0	-24.4	107567.6	5334.5	341.3	-.04
5995	105.02?	-139.0	-33.9	16269.8	7409.8	341.1	-.04
5996	105.51?	-278.0	-93.0	32539.5	20360.6	341.4	-.15

COMPUTED NODE DATA

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5992	105.48?	-919.0	-126.1	107567.6	27589.3	341.4	-.25
5986	105.43?	-114.0	-105.7	13343.5	23129.9	341.3	.15

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
HRI	5881		9923.1	167.57	146748.4	10.00	3.07E+5	1.66E-2
5881	A1		49106.5	393.85	345835.6	16.00	9.51E+5	1.44E-2
A1	A2		17857.3	1377.32	1208946.0	10.00	5.53E+5	1.59E-2
A2	A3		564.3	55.00	48204.1	2.50	6.99E+4	2.34E-2
A3	5922		157.0	5.86	5138.7	1.50	3.24E+4	2.75E-2
A3	A4		361.1	19.51	17119.9	1.50	7.46E+4	2.53E-2
A4	5923		157.0	5.86	5132.9	1.50	3.24E+4	2.75E-2
A4	A5		175.7	19.52	17107.9	1.50	3.63E+4	2.71E-2
A5	5924		157.0	5.85	5131.5	1.50	3.24E+4	2.75E-2
A2	A6		16383.6	374.67	330355.8	8.00	6.34E+5	1.64E-2
A6	5917		286.9	5.85	5130.5	1.50	5.93E+4	2.58E-2
A6	A7		15798.4	204.13	179934.6	8.00	6.12E+5	1.64E-2
A7	5918		167.4	44.80	39287.9	1.50	3.46E+4	2.73E-2
A7	A8		15489.9	20.41	17983.8	8.00	6.00E+5	1.65E-2
A8	5910		1271.3	40.95	35906.5	4.00	9.85E+4	2.11E-2
5910	5904		222.9	205.96	180587.6	3.00	2.30E+4	2.70E-2
A8	A9		14114.1	136.15	119855.0	8.00	5.47E+5	1.65E-2
A9	5911		938.8	28.18	25470.7	1.50	1.94E+5	2.41E-2
A9	A10		13019.2	136.18	119796.4	8.00	5.04E+5	1.66E-2
A10	5912		941.2	32.64	28637.5	3.00	9.72E+4	2.20E-2
A10	A11		11936.2	102.16	89814.2	8.00	4.62E+5	1.67E-2
A11	5919		174.1	58.32	51169.1	1.50	3.60E+4	2.72E-2
A11	A12		11659.5	34.05	29932.4	8.00	4.51E+5	1.67E-2
A12	5913		1270.9	40.87	35857.8	4.00	9.84E+4	2.11E-2
5913	5905		222.7	205.61	180342.9	3.00	2.30E+4	2.70E-2
A12	A13		10259.2	170.32	149628.5	8.00	3.97E+5	1.68E-2
A13	5951		941.2	32.61	28616.4	3.00	9.72E+4	2.20E-2
A13	A14		9176.1	68.14	59837.2	8.00	3.55E+5	1.70E-2
A14	5954		298.5	29.11	25565.8	1.50	6.16E+4	2.57E-2
A14	5953		323.5	29.10	25563.2	1.50	6.68E+4	2.55E-2
A14	A15		8407.2	156.72	137602.3	8.00	3.26E+5	1.71E-2
A15	A16		622.1	68.30	59946.6	2.50	7.71E+4	2.31E-2
A16	5955		174.6	19.41	17037.4	1.50	3.61E+4	2.72E-2
A16	A17		370.3	54.63	47938.3	2.50	4.59E+4	2.46E-2
A17	5956		104.6	19.41	17035.8	1.50	2.16E+4	2.92E-2
A17	5957		219.8	5.82	5110.7	1.50	4.54E+4	2.65E-2
A15	5950		258.9	116.22	102113.1	1.50	5.35E+4	2.60E-2
A15	A18		7296.0	107.00	94179.5	6.00	3.77E+5	1.77E-2
A18	5958		296.5	25.20	22139.6	1.50	6.12E+4	2.57E-2
A18	A19		6873.9	106.97	94122.0	6.00	3.55E+5	1.78E-2
A19	5952		949.3	48.81	42855.2	3.00	9.80E+4	2.20E-2
A19	A20		5787.2	107.02	94075.2	6.00	2.99E+5	1.80E-2
A20	5994		173.9	58.14	51044.8	1.50	3.59E+4	2.72E-2
A20	A21		5511.3	26.75	23512.8	6.00	2.85E+5	1.80E-2
A21	5989		1270.1	40.75	35770.8	4.00	9.84E+4	2.11E-2

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
5989	5985		222.3	204.97	179905.0	3.00	2.30E+4	2.70E-2
A21	A22		4166.8	69.60	61126.0	6.00	2.15E+5	1.84E-2
A22	5990		949.2	48.77	42827.1	3.00	9.80E+4	2.20E-2
A22	A23		3085.2	133.87	117532.4	6.00	1.59E+5	1.89E-2
A23	5991		949.3	48.76	42820.4	3.00	9.80E+4	2.20E-2
A23	A24		2012.6	53.55	47008.7	6.00	1.04E+5	1.99E-2
A24	5995		178.7	67.78	59521.0	1.50	3.69E+4	2.71E-2
A24	5996		376.8	186.05	163301.3	5.00	2.33E+4	2.61E-2
A24	5992		1276.5	40.73	35759.1	4.00	9.89E+4	2.11E-2

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
5992	5986		225.8	211.39	185554.7	3.00	2.33E+4	2.70E-2

COMPUTED TRAP LOSSES

5 percent trap leakage rate

Trap Steam Losses   Trap Heat Losses
334.4 lbs/hr   398161.5 Btus/hr

Ft. Dix Loop A
CHP 5881 loads

SYSTEM MASS FLOWS

(1)	Steam to loads:	43071. lbm/hr
(2)	Steam condensed in pipes:	6077. lbm/hr
(3)	Steam condensed in vaults:	0. lbm/hr
(4)	Steam lost to trap leakage:	334. lbm/hr
(5)	Total steam plant output:	49483. lbm/hr
(6)	Pipe and vault condensate returned:	1714. lbm/hr
(7)	Load condensate returned:	0. lbm/hr
(8)	Total condensate returned:	1714. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY
(M = Million)

(1)	Total pipe conduction heat losses:	5.338 MBtus/hr	43.94 %
(2)	Total pipe condensate heat losses:	1.370 MBtus/hr	11.28 %
(3)	Total load condensate heat losses:	5.041 MBtus/hr	41.50 %
(4)	Total vault conduction heat losses:	.000 MBtus/hr	.00 %
(5)	Total vault condensate heat losses:	.000 MBtus/hr	.00 %

(6) Total trap heat losses: .398 MBtus/hr 3.28 %
(7) Total heat losses: 12.148 MBtus/hr 100.00 %

(8) Total heat to loads: 46.249 MBtus/hr

(9) Total heat input to supply: 58.935 MBtus/hr
(10) Total heat returned to plant: .000 MBtus/hr
(11) Net heat input from plant: 58.935 MBtus/hr

DISTRIBUTION EFFICIENCY: 79.4% [1.0-(7)/(11)]

08/30/94 13:00:23
b05a

CHP 5881

SOLUTION COMPLETED IN 8 ITERATIONS

*** PROBLEM SUMMARY ***
55 NODES IN THE SYSTEM
54 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
5 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
54 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA							
NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
A1	110.00	19389.0?	-167.1	.0	36922.2	344.2	-1.00
B1	109.72?	.0	-304.5	.0	67220.6	344.0	.83
B2	109.28?	.0	-205.6	.0	45360.2	343.7	.73
B3	109.16?	.0	-129.4	.0	28546.4	343.6	1.15
B4	108.93?	.0	-125.7	.0	27708.4	343.5	-.46
B5	108.83?	.0	-328.5	.0	72404.4	343.4	.10
B6	108.82?	.0	-128.8	.0	28394.9	343.4	-.31
B7	108.65?	.0	-108.3	.0	23859.8	343.3	-.08
B8	108.29?	.0	-101.7	.0	22393.2	343.1	-.03
B9	108.46?	.0	-357.1	.0	78646.7	343.2	.21
B10	108.07?	.0	-265.4	.0	58398.5	343.0	-.18
B11	107.16?	.0	-174.1	.0	38242.5	342.4	-.01
B12	106.38?	.0	-85.6	.0	18778.1	341.9	.03
B13	106.24?	.0	-49.6	.0	10874.8	341.8	.00
B14	106.29?	.0	-93.2	.0	20438.6	341.9	.05

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
B15	106.09?	.0	-86.7	.0	19004.2	341.7	-.03
B16	107.98?	.0	-134.6	.0	29603.1	342.9	.13
B17	107.56?	.0	-130.3	.0	28630.3	342.7	-.01
B18	107.31?	.0	-119.7	.0	26289.3	342.5	.05
B19	106.86?	.0	-171.4	.0	37626.1	342.2	.13
B21	105.05?	.0	-176.9	.0	38678.3	341.1	.03
B22	104.16?	.0	-147.3	.0	32155.1	340.5	.03
B23	103.96?	.0	-135.8	.0	29635.4	340.4	-.03
B24	103.13?	.0	-193.0	.0	42032.3	339.9	.00
B25	106.79?	.0	-136.7	.0	30005.4	342.2	-.02
5850	109.71?	-114.0	-49.4	13343.5	10895.3	344.0	-.03
5845	106.35?	-919.0	-9.5	107567.6	2085.1	341.9	-.02
5851	108.96?	-919.0	-32.8	107567.6	7236.4	343.5	-.32
5852	107.26?	-919.0	-4.8	107567.6	1045.6	342.5	-.02
5853	104.82?	-278.0	-58.0	32539.5	12686.4	341.0	-.06
5841	107.15?	-919.0	-4.8	107567.6	1045.0	342.4	-.02
5842	106.98?	-919.0	-4.8	107567.6	1044.1	342.3	-.02
5843	108.12?	-278.0	-4.9	32539.5	1073.5	343.0	-.02
5844	107.49?	-139.0	-48.8	16269.8	10715.2	342.6	-.03
5840	108.45?	-114.0	-45.9	13343.5	10108.6	343.2	-.09
5831	107.13?	-303.0	-32.7	35465.7	7175.3	342.4	-.05
5812	105.47?	-919.0	-4.7	107567.6	1035.8	341.4	-.02
5832	106.21?	-89.0	-4.9	10417.3	1064.3	341.8	-.01
5833	105.94?	-159.0	-19.4	18610.7	4252.1	341.7	-.03
5834	106.13?	-211.0	-4.9	24697.3	1063.6	341.8	-.02
5813	104.55?	-278.0	-38.7	32539.5	8452.4	340.8	-.04
5814	105.85?	-139.0	-19.4	16269.8	4250.2	341.6	-.03
5835	105.40?	-195.0	-29.1	22824.5	6363.0	341.3	-.03
5810	107.97?	-114.0	-54.0	13343.5	11886.7	342.9	-.06
5811	104.14?	-919.0	-9.4	107567.6	2060.7	340.5	-.02
5806	107.21?	-919.0	-16.3	107567.6	3587.9	342.4	-.10
5803	103.33?	-919.0	-4.7	107567.6	1023.8	340.0	-.02
5804	103.98?	-278.0	-4.8	32539.5	1052.1	340.4	-.02
5807	102.43?	-919.0	-4.7	107567.6	1018.8	339.4	-.02
5805	103.79?	-139.0	-14.5	16269.8	3155.6	340.3	-.03
5755	102.43?	-408.0	-41.1	47755.8	8926.4	339.4	-.06
5756	99.50?	-626.0	-87.4	73272.4	18876.6	337.6	-.07
5801	106.76?	-114.0	-81.6	13343.5	17907.0	342.2	-.06
5802	106.64?	-919.0	-24.5	107567.6	5367.2	342.1	-.08

COMPUTED NODE DATA							
NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5854	104.58?	-139.0	-19.3	16269.8	4224.1	340.8	.02

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
A1	B1		19216.8	334.28	293398.7	10.00	5.95E+5	1.59E-2
B1	5850		169.4	98.70	86421.3	3.00	1.75E+4	2.85E-2
B1	5845		934.4	19.02	17107.5	1.50	1.93E+5	2.41E-2
B1	B2		17801.4	156.94	138474.2	8.00	6.89E+5	1.64E-2
B2	B3		2661.4	28.76	25231.2	4.00	2.06E+5	1.97E-2
B3	5851		957.6	65.65	57536.0	3.00	9.89E+4	2.20E-2
B3	B4		1567.2	164.47	144124.6	4.00	1.21E+5	2.06E-2
B4	5852		929.7	9.52	8554.7	1.50	1.92E+5	2.41E-2
B4	5853		506.1	77.42	68261.6	1.50	1.05E+5	2.48E-2
5853	5854		164.2	38.67	33969.9	1.50	3.39E+4	2.74E-2
B2	B5		14927.5	225.58	198495.7	8.00	5.78E+5	1.65E-2
B5	B6		2698.8	137.25	120242.5	8.00	1.05E+5	1.93E-2
B6	5841		929.7	9.52	8552.8	1.50	1.92E+5	2.41E-2
B6	B7		1634.4	110.92	97220.6	4.00	1.27E+5	2.05E-2
B7	5842		929.7	9.51	8549.6	1.50	1.92E+5	2.41E-2
B7	B8		590.4	96.18	84309.6	2.50	7.32E+4	2.33E-2
B8	5843		288.9	9.76	8556.8	1.50	5.97E+4	2.58E-2
B8	5844		193.7	97.51	85510.4	1.50	4.00E+4	2.68E-2
B5	B9		11894.0	294.25	258421.8	8.00	4.61E+5	1.67E-2
B9	5840		165.9	91.81	80446.3	3.00	1.71E+4	2.87E-2
B9	B10		11364.7	328.22	288239.0	8.00	4.40E+5	1.67E-2
B10	B11		3013.1	175.73	154466.3	4.00	2.33E+5	1.96E-2
B11	5831		341.6	65.35	57302.3	3.00	3.53E+4	2.51E-2
B11	5812		929.6	9.47	8522.3	1.50	1.92E+5	2.41E-2
B11	B12		1561.8	97.71	85884.3	3.00	1.61E+5	2.11E-2
B12	B13		561.5	40.98	35966.3	2.50	6.96E+4	2.34E-2
B13	5832		99.8	9.71	8520.6	1.50	2.06E+4	2.94E-2
B13	5833		184.3	38.82	34072.5	1.50	3.81E+4	2.70E-2
B13	5834		221.8	9.71	8519.9	1.50	4.58E+4	2.64E-2
B12	B14		908.7	32.59	28601.2	3.00	9.38E+4	2.21E-2
B14	5813		322.5	77.39	68046.0	1.50	6.66E+4	2.55E-2
B14	B15		486.9	76.48	67119.4	2.50	6.03E+4	2.38E-2
B15	5814		164.3	38.81	34063.4	1.50	3.39E+4	2.74E-2
B15	5835		230.0	58.16	51070.7	1.50	4.75E+4	2.63E-2
B10	B16		8080.4	26.85	23630.9	6.00	4.17E+5	1.76E-2
B16	5810		174.0	108.07	94716.0	3.00	1.80E+4	2.84E-2
B16	B17		7765.6	134.21	118090.7	6.00	4.01E+5	1.77E-2
B17	5811		934.3	18.88	17027.7	1.50	1.93E+5	2.41E-2
B17	B18		6695.1	107.41	94405.2	6.00	3.46E+5	1.78E-2
B18	5806		941.2	32.67	28658.4	3.00	9.72E+4	2.20E-2
B18	B19		5628.1	99.24	87389.0	5.00	3.49E+5	1.84E-2
B19	B21		4157.0	182.29	161075.0	4.00	3.22E+5	1.92E-2
B19	B25		1293.6	61.32	53792.3	4.00	1.00E+5	2.10E-2
B21	5803		929.5	9.40	8483.0	1.50	1.92E+5	2.41E-2
B21	B22		3044.7	162.09	142758.5	4.00	2.36E+5	1.96E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
B22	5804		288.6	9.65	8480.8	1.50	5.96E+4	2.58E-2
B22	5807		929.4	9.37	8466.3	1.50	1.92E+5	2.41E-2
B22	B23		1673.4	113.56	99812.2	4.00	1.30E+5	2.05E-2
B23	5805		159.3	28.94	25431.4	1.50	3.29E+4	2.75E-2
B23	B24		1372.5	129.19	113712.2	3.00	1.42E+5	2.13E-2
B24	5755		454.8	82.10	72240.0	2.00	7.04E+4	2.42E-2
B24	5756		718.9	174.73	154296.3	2.00	1.11E+5	2.33E-2
B25	5801		201.5	163.20	143143.0	3.00	2.08E+4	2.76E-2
B25	5802		949.4	48.93	42937.3	3.00	9.80E+4	2.20E-2

COMPUTED TRAP LOSSES

5 percent trap leakage rate

Trap Steam Losses	Trap Heat Losses
328.2 lbs/hr	390681.2 Btus/hr

CHP 5881

SYSTEM MASS FLOWS

(1)	Steam to loads:	14224. lbm/hr
(2)	Steam condensed in pipes:	4837. lbm/hr
(3)	Steam condensed in vaults:	0. lbm/hr
(4)	Steam lost to trap leakage:	328. lbm/hr
(5)	Total steam plant output:	19389. lbm/hr
(6)	Pipe and vault condensate returned:	1451. lbm/hr
(7)	Load condensate returned:	0. lbm/hr
(8)	Total condensate returned:	1451. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY
(M = Million)

(1)	Total pipe conduction heat losses:	4.252 MBtus/hr	57.69 %
(2)	Total pipe condensate heat losses:	1.063 MBtus/hr	14.42 %
(3)	Total load condensate heat losses:	1.665 MBtus/hr	22.59 %
(4)	Total vault conduction heat losses:	.000 MBtus/hr	.00 %
(5)	Total vault condensate heat losses:	.000 MBtus/hr	.00 %
(6)	Total trap heat losses:	.391 MBtus/hr	5.30 %
(7)	Total heat losses:	7.370 MBtus/hr	100.00 %
(8)	Total heat to loads:	15.268 MBtus/hr	
(9)	Total heat input to supply:	23.093 MBtus/hr	
(10)	Total heat returned to plant:	.000 MBtus/hr	
(11)	Net heat input from plant:	23.093 MBtus/hr	

DISTRIBUTION EFFICIENCY: 68.1% [1.0-(7)/(11)]

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Ft Dix Dist Sys
CHP 5881

SOLUTION COMPLETED IN 8 ITERATIONS

*** PROBLEM SUMMARY ***
56 NODES IN THE SYSTEM
55 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
5 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
55 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA							
NODE NAME	**PRESSURE (psig)**	**NODE FLOW (lbm/hr)**	**CONDS FLOW (lbm/hr)**	**FLOW LOSS (Btu/hr)**	**CONDS LOSS (Btu/hr)**	**TEMP (F)**	**RESIDUAL (lbm/hr)**
A1	110.00	23605.5?	-469.0	.0	103598.4	344.2	-7.66
C1	109.91?	.0	-2378.2	.0	525265.0	344.1	8.74
C2	106.10?	.0	-1971.3	.0	431994.9	341.8	-.63
C3	106.00?	.0	-346.8	.0	75972.4	341.7	-1.46
C4	106.00?	.0	-162.2	.0	35545.7	341.7	4.23
C5	105.99?	.0	-157.0	.0	34405.2	341.7	-2.28
C6	105.83?	.0	-124.7	.0	27312.2	341.6	-.03
C7	105.81?	.0	-489.8	.0	107277.9	341.6	-.08
C8	105.52?	.0	-560.9	.0	122770.7	341.4	-.34
C9	105.45?	.0	-94.4	.0	20662.7	341.3	.05
C10	105.33?	.0	-103.8	.0	22721.1	341.3	.18
C11	105.28?	.0	-135.0	.0	29535.8	341.2	-.09
C12	105.21?	.0	-106.5	.0	23293.4	341.2	.01
C13	105.20?	.0	-88.5	.0	19363.6	341.2	.07
C14	105.18?	.0	-85.9	.0	18790.0	341.2	-.03
C15	105.50?	.0	-98.8	.0	21629.2	341.4	.09
C16	105.25?	.0	-512.7	.0	112143.7	341.2	.25
C17	105.20?	.0	-85.2	.0	18645.7	341.2	.12
C18	105.02?	.0	-86.1	.0	18830.5	341.1	-.07
C19	104.34?	.0	-112.8	.0	24632.0	340.7	-.01
C20	105.12?	.0	-299.2	.0	65437.6	341.1	-.15
C21	104.88?	.0	-85.9	.0	18766.8	341.0	-.02
C22	104.97?	.0	-91.3	.0	19965.4	341.0	-.06
C23	104.86?	.0	-112.5	.0	24583.8	341.0	-.04
C24	104.72?	.0	-81.1	.0	17723.1	340.9	-.01

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
C25	104.59?	.0	-59.0	.0	12895.1	340.8	-.01
C26	102.40?	.0	-52.8	.0	11481.9	339.4	.02
5751	104.29?	-919.0	-4.7	107567.6	1029.2	340.6	-.02
5752	104.29?	-919.0	-4.7	107567.6	1029.2	340.6	-.02
5753	104.09?	-278.0	-38.6	32539.5	8433.5	340.5	-.04
5754	105.43?	-139.0	-29.1	16269.8	6363.4	341.3	-.04
5750	105.98?	-114.0	-57.0	13343.5	12487.7	341.7	-.07
5745	100.51?	-919.0	-14.0	107567.6	3036.5	338.2	-.02
5740	105.38?	-114.0	-14.5	13343.5	3180.3	341.3	-.03
5741	103.74?	-919.0	-4.7	107567.6	1026.1	340.3	-.02
5742	103.61?	-919.0	-4.7	107567.6	1025.4	340.2	-.02
5743	103.72?	-278.0	-33.8	32539.5	7364.3	340.3	-.04
5744	104.39?	-139.0	-48.3	16269.8	10556.0	340.7	-.04
5734	104.72?	-211.0	-19.3	24697.3	4226.8	340.9	-.04
5731	105.13?	-303.0	-48.7	35465.7	10659.5	341.1	-.07
5732	105.12?	-89.0	-9.7	10417.3	2117.5	341.1	-.02
5733	105.07?	-83.0	-19.4	9715.0	4234.0	341.1	-.03
5710	105.23?	-114.0	-65.0	13343.5	14219.3	341.2	-.08
5711	101.79?	-1301.0	-4.5	152280.2	968.0	339.0	-.02
5712	103.30?	-919.0	-4.7	107567.6	1023.6	340.0	-.02
5713	102.01?	-278.0	-48.1	32539.5	10439.6	339.2	-.04
5714	102.29?	-139.0	-9.6	16269.8	2088.0	339.3	-.03
5735	101.97?	-195.0	-19.2	22824.5	4169.8	339.1	-.03
5706	103.16?	-919.0	-4.7	107567.6	1022.9	339.9	-.02
5701	104.87?	-114.0	-56.8	13343.5	12420.1	341.0	-.05
5702	103.25?	-919.0	-4.7	107567.6	1023.4	340.0	-.02
5703	104.76?	-919.0	-16.2	107567.6	3545.5	340.9	-.03
5707	99.37?	-919.0	-14.0	107567.6	3017.4	337.5	-.03
5704	104.42?	-278.0	-4.8	32539.5	1054.4	340.7	-.02

COMPUTED NODE DATA

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5705	104.10?	-139.0	-33.8	16269.8	7376.4	340.5	-.04
5720	104.73?	-148.0	-43.5	17323.2	9515.8	340.9	-.04

COMPUTED PIPE FLOWS AND PARAMETERS

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
A1	C1		23138.1	937.95	821419.9	16.00	4.48E+5	1.51E-2
C1	C2		20745.0	3818.50	3361023.0	10.00	6.43E+5	1.58E-2
C2	C3		18768.4	124.07	109138.3	10.00	5.81E+5	1.59E-2
C3	C4		2819.2	124.36	109125.8	10.00	8.73E+4	1.95E-2
C4	5751		929.6	9.43	8500.7	1.50	1.92E+5	2.41E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
C4	C5		1717.3	190.69	167325.3	10.00	5.32E+4	2.13E-2
C5	5752		929.6	9.43	8500.7	1.50	1.92E+5	2.41E-2
C5	C6		627.0	113.95	100013.9	3.00	6.47E+4	2.30E-2
C6	5753		322.5	77.29	67978.7	1.50	6.66E+4	2.55E-2
C6	5754		174.0	58.16	51058.2	1.50	3.59E+4	2.72E-2
C3	5750		176.9	114.00	100030.6	3.00	1.83E+4	2.83E-2
C3	C7		15421.0	331.08	290943.5	10.00	4.78E+5	1.61E-2
C7	5745		938.7	28.05	25392.3	1.50	1.94E+5	2.41E-2
C7	C8		13986.7	620.54	545233.7	10.00	4.33E+5	1.62E-2
C8	C15		436.6	81.48	71520.2	4.00	3.38E+4	2.46E-2
C15	5740		134.4	29.07	25518.6	1.50	2.78E+4	2.81E-2
C15	5720		197.4	87.09	76502.1	1.50	4.08E+4	2.68E-2
C8	C9		3826.1	80.29	70506.7	6.00	1.98E+5	1.86E-2
C9	5741		929.5	9.41	8490.5	1.50	1.92E+5	2.41E-2
C9	C10		2796.2	99.14	87070.5	5.00	1.73E+5	1.93E-2
C10	5742		929.5	9.41	8488.3	1.50	1.92E+5	2.41E-2
C10	C11		1756.8	99.15	87054.5	5.00	1.09E+5	2.02E-2
C11	C12		623.1	48.75	42801.1	3.00	6.43E+4	2.30E-2
C12	5743		317.6	67.55	59417.3	1.50	6.56E+4	2.56E-2
C12	5744		193.2	96.69	84943.3	1.50	3.99E+4	2.68E-2
C11	C13		992.8	122.12	107217.8	4.00	7.69E+4	2.17E-2
C13	5734		236.2	38.69	33989.3	1.50	4.88E+4	2.63E-2
C13	C14		662.1	16.25	14265.3	3.00	6.84E+4	2.28E-2
C14	5731		357.6	97.48	85584.7	3.00	3.69E+4	2.49E-2
C14	5732		104.6	19.36	17001.6	1.50	2.16E+4	2.92E-2
C14	5733		108.2	38.73	34001.1	1.50	2.24E+4	2.90E-2
C8	C16		9157.4	339.52	298397.7	8.00	3.55E+5	1.70E-2
C16	5710		184.8	130.01	114133.6	3.00	1.91E+4	2.81E-2
C16	C17		3307.2	80.24	70466.6	6.00	1.71E+5	1.88E-2
C17	5711		1311.2	8.92	8470.1	1.50	2.71E+5	2.38E-2
C17	C18		1904.7	81.33	71457.6	4.00	1.48E+5	2.02E-2
C18	5712		929.5	9.40	8482.4	1.50	1.92E+5	2.41E-2
C18	C19		883.3	81.51	71679.3	2.50	1.09E+5	2.24E-2
C19	5713		331.8	96.11	84641.4	1.50	6.85E+4	2.55E-2
C19	C26		432.8	48.01	42338.8	1.50	8.94E+4	2.50E-2
C26	5714		154.3	19.21	16896.8	1.50	3.19E+4	2.76E-2
C26	5735		219.9	38.39	33781.5	1.50	4.54E+4	2.65E-2
C16	C20		5146.6	475.53	417577.2	8.00	1.99E+5	1.78E-2
C20	C21		1197.9	48.67	42778.3	3.00	1.24E+5	2.15E-2
C21	5706		929.5	9.39	8479.9	1.50	1.92E+5	2.41E-2
C21	5701		176.7	113.65	99788.3	3.00	1.82E+4	2.83E-2
C20	C22		3643.8	74.23	65253.9	5.00	2.26E+5	1.89E-2
C22	5702		929.5	9.40	8481.5	1.50	1.92E+5	2.41E-2
C22	C23		2617.1	99.02	86980.9	5.00	1.62E+5	1.94E-2
C23	5703		941.1	32.45	28507.2	3.00	9.72E+4	2.20E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
C23	C24		1557.7	93.48	82120.1	4.00	1.21E+5	2.06E-2
C24	5707		938.6	27.94	25329.7	1.50	1.94E+5	2.41E-2
C24	C25		532.2	40.80	35837.9	2.50	6.59E+4	2.35E-2
C25	5704		288.7	9.66	8488.9	1.50	5.96E+4	2.58E-2

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
C25	5705		178.6	67.60	59401.2	1.50	3.69E+4	2.71E-2

COMPUTED TRAP LOSSES

5 percent trap leakage rate

Trap Steam Losses	Trap Heat Losses
329.1 lbs/hr	391733.9 Btus/hr

Ft Dix Dist Sys
CHP 5881

SYSTEM MASS FLOWS

(1)	Steam to loads:	13644. lbm/hr
(2)	Steam condensed in pipes:	9633. lbm/hr
(3)	Steam condensed in vaults:	0. lbm/hr
(4)	Steam lost to trap leakage:	329. lbm/hr
(5)	Total steam plant output:	23606. lbm/hr
(6)	Pipe and vault condensate returned:	2890. lbm/hr
(7)	Load condensate returned:	0. lbm/hr
(8)	Total condensate returned:	2890. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY
(M = Million)

(1)	Total pipe conduction heat losses:	8.470 MBtus/hr	67.37 %
(2)	Total pipe condensate heat losses:	2.114 MBtus/hr	16.81 %
(3)	Total load condensate heat losses:	1.597 MBtus/hr	12.70 %
(4)	Total vault conduction heat losses:	.000 MBtus/hr	.00 %
(5)	Total vault condensate heat losses:	.000 MBtus/hr	.00 %
(6)	Total trap heat losses:	.392 MBtus/hr	3.12 %
(7)	Total heat losses:	12.572 MBtus/hr	100.00 %
(8)	Total heat to loads:	14.640 MBtus/hr	
(9)	Total heat input to supply:	28.114 MBtus/hr	
(10)	Total heat returned to plant:	.000 MBtus/hr	
(11)	Net heat input from plant:	28.114 MBtus/hr	

DISTRIBUTION EFFICIENCY: 55.3% [1.0-(7)/(11)]

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Ft Dix Dist Sys
CHP 5426

SOLUTION COMPLETED IN 8 ITERATIONS

*** PROBLEM SUMMARY ***
49 NODES IN THE SYSTEM
48 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
10 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
48 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5426	110.00	27437.8?	-1385.3	.0	306028.5	344.2	-.65
D1	105.67?	.0	-1452.0	.0	317902.5	341.5	1.18
D2	105.50?	.0	-454.0	.0	99367.8	341.4	-.05
D3	102.58?	.0	-484.6	.0	105401.5	339.5	-.23
D4	102.52?	.0	-92.3	.0	20083.0	339.5	-.06
D5	102.37?	.0	-123.8	.0	26912.1	339.4	.12
D6	102.32?	.0	-84.0	.0	18261.0	339.4	-.34
D7	102.31?	.0	-56.8	.0	12348.8	339.4	.33
D8	102.29?	.0	-193.3	.0	42009.1	339.4	-.30
D9	102.25?	.0	-68.2	.0	14830.8	339.3	-.04
D10	102.23?	.0	-80.2	.0	17423.4	339.3	.10
D11	102.05?	.0	-211.3	.0	45908.3	339.2	-1.00
D12	101.50?	.0	-105.7	.0	22937.1	338.8	-.71
D13	100.92?	.0	-188.1	.0	40769.8	338.5	1.63
D14	101.27?	.0	-273.2	.0	59267.2	338.7	2.01
D15	98.17?	.0	-125.1	.0	26950.4	336.7	-.06
D16	97.91?	.0	-89.2	.0	19214.2	336.5	.12
D17	97.33?	.0	-145.9	.0	31376.1	336.1	.05
D18	97.15?	.0	-117.5	.0	25256.8	336.0	-.09
5605	105.61?	-139.0	-4.8	16269.8	1061.2	341.4	-.01
5604	105.41?	-278.0	-86.7	32539.5	18976.9	341.3	.09
5603	105.24?	-1301.0	-102.6	152280.2	22450.1	341.2	-.05
5602	105.12?	-1301.0	-81.4	152280.2	17798.4	341.1	.07
5601	105.12?	-114.0	-40.7	13343.5	8900.2	341.1	-.21
5614	102.14?	-139.0	-28.8	16269.8	6261.4	339.3	-.01

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5613	102.34?	-278.0	-4.8	32539.5	1043.6	339.4	-.01
5612	98.86?	-1301.0	-4.4	152280.2	948.1	337.1	-.02
5611	98.80?	-1301.0	-4.4	152280.2	947.7	337.1	-.02
5610	102.21?	-114.0	-78.5	13343.5	17059.4	339.3	-.21
5606	101.59?	-1301.0	-48.2	152280.2	10466.9	338.9	.06
5635	101.83?	-144.0	-28.8	16855.0	6251.7	339.1	-.01
5634	102.06?	-211.0	-7.7	24697.3	1668.2	339.2	-.01
5633	102.16?	-159.0	-4.8	18610.7	1043.2	339.3	-.02
5632	102.20?	-89.0	-4.8	10417.3	1043.6	339.3	-.02
5631	102.19?	-303.0	-40.3	35465.7	8755.0	339.3	-.09
5644	101.79?	-139.0	-19.2	16269.8	4166.2	339.0	-.02
5643	101.90?	-278.0	-80.8	32539.5	17546.7	339.1	-.16
5642	97.96?	-1301.0	-4.4	152280.2	942.2	336.5	-.04
5641	101.00?	-1301.0	-60.2	152280.2	13054.6	338.5	-.23
5640	100.91?	-114.0	-48.2	13343.5	10438.7	338.5	.15
5645	99.18?	-1301.0	-119.8	152280.2	25875.3	337.3	-.48
5660	101.18?	-214.0	-47.1	25048.4	10224.8	338.6	.08
5646	99.05?	-1301.0	-193.2	152280.2	41699.9	337.3	-.58
5654	97.72?	-139.0	-28.4	16269.8	6122.4	336.4	-.04
5653	97.71?	-278.0	-4.7	32539.5	1019.3	336.4	-.03
5652	95.47?	-919.0	-4.6	107567.6	978.4	334.9	-.02
5656	95.64?	-2693.0	-31.3	315211.8	6701.1	335.0	-.08
5651	93.48?	-1301.0	-4.3	152280.2	912.2	333.5	-.02
5650	97.13?	-114.0	-63.5	13343.5	13651.5	336.0	-.07

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
5426	D1		26040.8	2770.70	2446819.0	10.00	8.07E+5	1.56E-2
D1	5605		155.7	9.69	8509.9	1.50	3.22E+4	2.75E-2
D1	D2		24420.1	123.55	109027.8	10.00	7.57E+5	1.57E-2
D2	5604		3352.6	49.56	43541.2	5.00	2.08E+5	1.90E-2
5604	5603		2975.9	123.88	108823.0	5.00	1.84E+5	1.92E-2
5603	5602		1560.5	81.38	71469.0	4.00	1.21E+5	2.06E-2
5602	5601		166.3	81.39	71459.4	4.00	1.29E+4	3.01E-2
D2	D3		20601.8	734.91	654563.1	8.00	7.98E+5	1.63E-2
D3	5614		179.3	57.63	50692.7	1.50	3.70E+4	2.71E-2
D3	D4		4895.1	42.45	37362.4	6.00	2.53E+5	1.82E-2
D4	5613		294.3	9.60	8450.1	1.50	6.08E+4	2.57E-2
D4	D5		4497.0	132.63	116730.3	6.00	2.32E+5	1.83E-2
D5	5612		1316.6	8.79	8415.9	1.50	2.72E+5	2.38E-2
D5	D6		3045.0	106.14	93362.4	6.00	1.57E+5	1.90E-2
D6	5611		1316.6	8.79	8414.7	1.50	2.72E+5	2.38E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
D6	D7		1633.2	53.08	46677.7	6.00	8.43E+4	2.05E-2
D7	5610		1564.5	60.53	53258.0	4.00	1.21E+5	2.06E-2
5610	5606		1360.7	96.45	84973.0	3.00	1.41E+5	2.13E-2
D3	D8		15031.4	134.15	118589.1	8.00	5.82E+5	1.65E-2
D8	5635		184.3	57.58	50658.6	1.50	3.81E+4	2.70E-2
D8	D9		1037.0	60.55	53259.4	4.00	8.03E+4	2.16E-2
D8	D11		13605.7	134.22	118519.2	8.00	5.27E+5	1.66E-2
D9	5634		230.2	15.36	13511.8	1.50	4.75E+4	2.63E-2
D9	D10		727.1	60.55	53255.5	4.00	5.63E+4	2.26E-2
D10	5633		175.3	9.60	8445.6	1.50	3.62E+4	2.71E-2
D10	5632		105.3	9.60	8446.0	1.50	2.17E+4	2.91E-2
D10	5631		354.7	80.57	70859.1	3.00	3.66E+4	2.49E-2
D11	5644		169.6	38.37	33761.8	1.50	3.50E+4	2.72E-2
D11	5643		4981.8	39.18	34567.4	5.00	3.09E+5	1.85E-2
5643	D12		4611.7	122.40	107955.9	5.00	2.86E+5	1.86E-2
D12	5642		1316.4	8.75	8398.9	1.50	2.72E+5	2.38E-2
D12	5641		3178.8	80.25	70850.3	4.00	2.46E+5	1.95E-2
5641	D13		1806.4	40.20	35402.0	4.00	1.40E+5	2.03E-2
D13	5640		173.7	96.33	84784.3	3.00	1.79E+4	2.84E-2
D13	5645		1431.6	239.69	211546.2	3.00	1.48E+5	2.12E-2
D11	D14		8232.5	210.82	186439.5	6.00	4.25E+5	1.76E-2
D14	5660		272.6	94.30	82986.8	2.50	3.38E+4	2.57E-2
D14	5646		7673.1	241.38	215163.1	5.00	4.75E+5	1.81E-2
5646	D15		6168.3	145.00	128640.4	5.00	3.82E+5	1.83E-2
D15	5654		178.5	56.90	50186.2	1.50	3.69E+4	2.71E-2
D15	D16		5853.7	48.30	42823.4	5.00	3.63E+5	1.83E-2
D16	5653		293.8	9.47	8361.7	1.50	6.07E+4	2.57E-2
D16	D17		5459.4	120.71	106953.1	5.00	3.38E+5	1.84E-2
D17	5652		934.4	9.14	8334.2	1.50	1.93E+5	2.41E-2
D17	5656		2735.1	62.57	55948.8	3.00	2.82E+5	2.05E-2
D17	D18		1632.9	99.42	87751.3	4.00	1.26E+5	2.05E-2
D18	5651		1315.9	8.56	8312.9	1.50	2.72E+5	2.38E-2
D18	5650		188.5	127.04	112069.0	3.00	1.95E+4	2.79E-2

COMPUTED TRAP LOSSES

10 percent trap leakage rate

Trap Steam Losses	Trap Heat Losses
559.7 lbs/hr	665934.4 Btus/hr

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SYSTEM MASS FLOWS

(1) Steam to loads: 19866. lbm/hr

(2)	Steam condensed in pipes:	7012. lbm/hr
(3)	Steam condensed in vaults:	0. lbm/hr
(4)	Steam lost to trap leakage:	560. lbm/hr
(5)	Total steam plant output:	27438. lbm/hr
(6)	Pipe and vault condensate returned:	2104. lbm/hr
(7)	Load condensate returned:	0. lbm/hr
(8)	Total condensate returned:	2104. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY
(M = Million)

(1)	Total pipe conduction heat losses:	6.199 MBtus/hr	57.83 %
(2)	Total pipe condensate heat losses:	1.530 MBtus/hr	14.27 %
(3)	Total load condensate heat losses:	2.325 MBtus/hr	21.69 %
(4)	Total vault conduction heat losses:	.000 MBtus/hr .00 %	
(5)	Total vault condensate heat losses:	.000 MBtus/hr .00 %	
(6)	Total trap heat losses:	.666 MBtus/hr 6.21 %	
(7)	Total heat losses:	10.721 MBtus/hr	100.00 %
(8)	Total heat to loads:	21.306 MBtus/hr	
(9)	Total heat input to supply:	32.679 MBtus/hr	
(10)	Total heat returned to plant:	.000 MBtus/hr	
(11)	Net heat input from plant:	32.679 MBtus/hr	

DISTRIBUTION EFFICIENCY: 67.2% [1.0-(7)/(11)]

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Ft Dix Dist Sys
CHP 5426

SOLUTION COMPLETED IN 7 ITERATIONS

*** PROBLEM SUMMARY ***
31 NODES IN THE SYSTEM
30 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
10 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
30 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA							
NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
5426	110.00	24760.1?	-123.4	.0	27263.7	344.2	-4.59
E1	109.97?	.0	-353.4	.0	78053.9	344.1	-4.29
E2	109.73?	.0	-608.6	.0	134365.3	344.0	-2.03
E3	109.53?	.0	-376.2	.0	83021.4	343.9	-2.98
E4	109.24?	.0	-308.8	.0	68105.8	343.7	-.52
EA	109.53?	.0	-412.9	.0	91118.7	343.9	1.18
5501	107.51?	-1236.0	-132.1	144672.0	29036.4	342.6	.33
5502	107.56?	-1236.0	-103.7	144672.0	22799.9	342.7	.73
5503	107.61?	-1236.0	-107.7	144672.0	23671.2	342.7	.80
5504	107.72?	-1236.0	-269.2	144672.0	59187.4	342.8	1.74
5505	108.51?	-636.0	-363.6	74442.9	80070.3	343.2	-.17
5506	109.16?	-1236.0	-94.6	144672.0	20865.4	343.6	-.06
5507	109.11?	-1236.0	-108.2	144672.0	23847.5	343.6	1.34
5508	109.09?	-1236.0	-104.2	144672.0	22970.2	343.6	.33
5509	109.09?	-71.0	-101.5	8310.4	22385.0	343.6	.05
5510	107.33?	-68.0	-116.5	7959.3	25592.8	342.5	.43
5511	107.31?	-68.0	-34.3	7959.3	7526.2	342.5	.18
5512	109.08?	-83.0	-51.4	9715.0	11338.8	343.6	.11
5513	108.79?	-209.0	-102.8	24463.2	22646.8	343.4	.45
5514	108.56?	-169.0	-14.7	19781.2	3229.1	343.3	.30
5515	108.81?	-845.0	-167.5	98906.0	36909.7	343.4	.16
5516	108.85?	-1236.0	-100.1	144672.0	22061.6	343.4	1.01
5517	108.97?	-1236.0	-104.1	144672.0	22943.9	343.5	.36
5518	109.08?	-1236.0	-189.1	144672.0	41694.7	343.6	1.30
5519	108.89?	-74.0	-152.9	8661.6	33692.8	343.5	-.06
5520	108.90?	-1236.0	-100.1	144672.0	22071.8	343.5	1.07
5521	108.96?	-1236.0	-117.6	144672.0	25929.8	343.5	.57
5522	109.04?	-1236.0	-271.0	144672.0	59751.9	343.6	.88
5523	108.56?	-633.0	-48.1	74091.8	10599.0	343.3	.87
5524	108.86?	-68.0	-41.3	7959.3	9098.1	343.5	.21
5525	108.88?	-68.0	-144.1	7959.3	31754.0	343.5	.23

COMPUTED PIPE FLOWS AND PARAMETERS								
FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
5426	E1		24629.0	246.84	216177.1	16.00	4.77E+5	1.51E-2
E1	E2		24267.6	459.88	403418.5	12.00	6.26E+5	1.54E-2
E2	E3		11586.2	171.57	150556.8	8.00	4.49E+5	1.67E-2
E3	5522		5515.0	310.67	272476.5	6.00	2.85E+5	1.80E-2
5522	5523		694.1	96.24	84368.0	2.50	8.60E+4	2.29E-2
5522	5521		3300.8	135.12	118397.2	6.00	1.70E+5	1.88E-2
5521	5520		1934.5	100.13	87731.9	5.00	1.20E+5	2.00E-2
5520	5519		585.1	100.14	87726.0	5.00	3.63E+4	2.39E-2
5519	5525		346.1	205.59	180095.1	4.00	2.68E+4	2.57E-2
5525	5524		121.7	82.56	72325.9	2.50	1.51E+4	2.98E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
E3	5518		5685.7	270.13	236945.5	6.00	2.94E+5	1.80E-2
5518	5517		4247.2	108.07	94723.0	6.00	2.19E+5	1.84E-2
5517	5516		2894.5	100.09	87728.5	5.00	1.79E+5	1.92E-2
5516	5515		1545.3	100.12	87713.4	5.00	9.57E+4	2.05E-2
5515	5514		196.1	29.32	25696.4	1.50	4.05E+4	2.68E-2
5515	5513		324.4	205.54	180063.6	4.00	2.51E+4	2.61E-2
E2	EA		12062.7	585.71	513205.3	10.00	3.74E+5	1.63E-2
EA	E4		11636.4	240.03	210672.2	8.00	4.51E+5	1.67E-2
E4	5506		4384.6	81.09	71068.5	6.00	2.26E+5	1.83E-2
5506	5507		3041.8	108.14	94744.4	6.00	1.57E+5	1.90E-2
5507	5508		1684.2	108.16	94737.2	6.00	8.70E+4	2.04E-2
5508	5509		331.5	100.20	87760.8	5.00	2.05E+4	2.69E-2
5509	5512		146.7	102.85	90085.2	4.00	1.14E+4	3.11E-2
E4	5505		6931.3	296.44	260407.0	6.00	3.58E+5	1.78E-2
5505	5504		5919.8	430.69	378166.4	6.00	3.06E+5	1.79E-2
5504	5503		4400.9	107.67	94451.3	6.00	2.27E+5	1.83E-2
5503	5502		3044.3	107.69	94434.5	6.00	1.57E+5	1.90E-2
5502	5501		1691.8	99.76	87472.9	5.00	1.05E+5	2.03E-2
5501	5510		311.4	164.46	144208.1	2.50	3.86E+4	2.52E-2
5510	5511		114.4	68.51	60074.1	2.50	1.42E+4	3.02E-2

COMPUTED TRAP LOSSES

10 percent trap leakage rate

Trap Steam Losses	Trap Heat Losses
376.7 lbs/hr	448606.4 Btus/hr

Ft Dix Dist Sys
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SYSTEM MASS FLOWS

(1) Steam to loads: 19060. lbm/hr
(2) Steam condensed in pipes: 5323. lbm/hr
(3) Steam condensed in vaults: 0. lbm/hr
(4) Steam lost to trap leakage: 377. lbm/hr
(5) Total steam plant output: 24760. lbm/hr

(6) Pipe and vault condensate returned: 1597. lbm/hr
(7) Load condensate returned: 0. lbm/hr
(8) Total condensate returned: 1597. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY
(M = Million)

(1) Total pipe conduction heat losses: 4.668 MBtus/hr 54.78 %
(2) Total pipe condensate heat losses: 1.174 MBtus/hr 13.77 %
(3) Total load condensate heat losses: 2.231 MBtus/hr 26.18 %

(4)	Total vault conduction heat losses:	.000 MBtus/hr	.00 %
(5)	Total vault condensate heat losses:	.000 MBtus/hr	.00 %
(6)	Total trap heat losses:	.449 MBtus/hr	5.26 %
(7)	Total heat losses:	8.521 MBtus/hr	100.00 %
(8)	Total heat to loads:	20.466 MBtus/hr	
(9)	Total heat input to supply:	29.489 MBtus/hr	
(10)	Total heat returned to plant:	.000 MBtus/hr	
(11)	Net heat input from plant:	29.489 MBtus/hr	

DISTRIBUTION EFFICIENCY: 71.1% [1.0-(7)/(11)]

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Ft Dix Dist Sys
CHP 5426

SOLUTION COMPLETED IN 9 ITERATIONS
SOME NODES MAY NOT BE BALANCED

*** PROBLEM SUMMARY ***
42 NODES IN THE SYSTEM
41 PIPES IN THE SYSTEM
0 VALVES OR REGULATORS
10 PERCENT TRAP LEAKAGE
0 VAULTS IN THE SYSTEM
0 UNKNOWN PARAMETERS
41 UNKNOWN PRESSURES
1 UNKNOWN FLOWS

COMPUTED NODE DATA

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
E1	110.00	37904.7?	-457.0	.0	100945.1	344.2	-1.40
E5	108.88?	.0	-1138.2	.0	250856.5	343.5	3.26
E6	108.82?	.0	-442.1	.0	97426.0	343.4	.12
E7	108.77?	.0	-539.1	.0	118786.3	343.4	-.07
E7A	108.13?	.0	-115.6	.0	25446.1	343.0	-.08
E8	108.64?	.0	-1053.6	.0	232109.6	343.3	-.71
E9	107.66?	.0	-1400.1	.0	307817.2	342.7	-10.12
E10	106.23?	.0	-505.5	.0	110795.6	341.8	-.18
E10A	105.95?	.0	-184.0	.0	40302.5	341.7	.01
E11	105.62?	.0	-184.2	.0	40323.9	341.5	-.09

NODE NAME	PRESSURE (psig)	NODE FLOW (lbm/hr)	CONDS FLOW (lbm/hr)	FLOW LOSS (Btu/hr)	CONDS LOSS (Btu/hr)	TEMP (F)	RESIDUAL (lbm/hr)
E12	107.40?	.0	-335.7	.0	73771.8	342.6	-.74
E13	107.31?	.0	-143.1	.0	31445.4	342.5	-.04
5401	108.78?	-208.0	-274.5	24346.1	60483.0	343.4	-.52
5402	108.77?	-71.0	-120.1	8310.4	26459.9	343.4	.08
5403	108.76?	-845.0	-220.7	98906.0	48621.2	343.4	.58
5404	108.75?	-74.0	-211.8	8661.6	46667.9	343.4	-.53
5405	108.74?	-208.0	-101.4	24346.1	22348.1	343.4	.18
5406	108.73?	-74.0	-120.1	8661.6	26472.5	343.4	-.04
5407	108.69?	-68.0	-68.8	7959.3	15151.5	343.4	-.06
5408	108.64?	-83.0	-53.7	9715.0	11827.1	343.3	-.05
5410	108.45?	-68.0	-44.0	7959.3	9684.5	343.2	-.05
5411	107.10?	-636.0	-47.5	74442.9	10434.2	342.4	-.03
5418	107.50?	-2049.0	-13.5	239832.5	2977.0	342.6	-.02
5428	108.64?	-68.0	-24.4	7959.3	5384.4	343.3	-.03
5429	106.84?	-169.0	-68.2	19781.2	14967.3	342.2	-.05
5430	108.56?	-68.0	-61.9	7959.3	13628.2	343.3	-.07
5431	108.60?	-208.0	-209.4	24346.1	46123.5	343.3	.04
5432	108.66?	-74.0	-173.6	8661.6	38237.6	343.3	-.02
5433	108.68?	-208.0	-162.1	24346.1	35702.8	343.3	-.12
5434	108.73?	-74.0	-176.6	8661.6	38921.6	343.4	.52
5435	108.73?	-845.0	-240.1	98906.0	52911.1	343.4	-.60
5441	107.16?	-314.0	-19.5	36753.3	4275.5	342.4	-.04
5215	106.06?	-1314.0	-81.6	153801.8	17871.2	341.7	-.11
5219	105.82?	-137.0	-41.4	16035.7	9075.6	341.6	-.02
5240	105.58?	-720.0	-81.3	84275.0	17806.3	341.4	-.07
5252	107.58?	.0	-719.7	.0	158204.5	342.7	15.21
5256	107.30?	-349.0	-16.3	40850.0	3590.4	342.5	.01
5257	107.30?	-216.0	-32.7	25282.5	7181.0	342.5	.03
5258	107.30?	-216.0	-32.7	25282.5	7181.0	342.5	.03
5275	105.13?	-566.0	-17.7	66249.5	3873.2	341.1	-.04
5276	105.30?	-566.0	-11.8	66249.5	2583.9	341.3	-.04
HOSP	107.24?	-16708.0	-249.2	1955648.0	54744.2	342.5	-4.13

COMPUTED PIPE FLOWS AND PARAMETERS

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
E1	E5		37436.9	913.93	806138.0	12.00	9.66E+5	1.50E-2
E5	E6		4172.8	343.12	300619.3	8.00	1.62E+5	1.82E-2
E6	5411		695.5	95.03	83493.6	2.00	1.08E+5	2.34E-2
E6	5401		3022.9	446.03	390763.8	8.00	1.17E+5	1.90E-2
5401	5402		2528.8	102.93	90171.6	8.00	9.79E+4	1.95E-2
5402	5403		2325.5	137.23	120227.0	8.00	9.01E+4	1.97E-2
5403	5404		1123.1	216.12	189338.0	6.00	5.80E+4	2.17E-2
5403	5410		124.1	87.96	77075.9	1.50	2.56E+4	2.84E-2
5404	5405		676.9	100.10	87697.1	5.00	4.19E+4	2.33E-2
5404	5408		148.8	107.38	94076.0	2.00	2.30E+4	2.80E-2

FROM NODE	TO NODE	STATUS	FLOW (lbm/hr)	CONDENSATE (lbm/hr)	HEAT LOSS (Btu/hr)	DIAMETER (in)	RE NUMBER	FRIC FACTOR
5405	5406		355.1	102.75	90018.6	4.00	2.75E+4	2.56E-2
5406	5407		148.9	137.54	120502.5	2.50	1.84E+4	2.86E-2
E5	E7		3951.1	686.20	601208.6	8.00	1.53E+5	1.84E-2
E7	5428		104.5	48.88	42829.2	1.50	2.16E+4	2.92E-2
E7	5435		3295.4	343.06	300558.9	8.00	1.28E+5	1.88E-2
5435	5434		2198.8	137.22	120217.9	8.00	8.51E+4	1.99E-2
5434	5433		1935.4	216.08	189317.9	6.00	9.99E+4	2.00E-2
5433	5432		1553.4	108.03	94652.7	6.00	8.02E+4	2.06E-2
5432	5429		249.1	136.39	119679.9	1.50	5.14E+4	2.61E-2
5432	5431		1044.6	102.71	89999.1	4.00	8.09E+4	2.15E-2
5431	5430		141.9	123.75	108422.7	2.50	1.76E+4	2.89E-2
5431	E7A		473.1	192.33	168580.6	2.50	5.86E+4	2.38E-2
E7A	5441		345.4	38.93	34186.2	1.50	7.13E+4	2.54E-2
E5	E8		28159.4	333.11	292722.6	12.00	7.27E+5	1.52E-2
E8	5418		2074.6	27.09	24068.0	2.50	2.57E+5	2.13E-2
E8	E9		25019.8	1747.06	1534814.0	12.00	6.46E+5	1.53E-2
E9	E10		3123.8	970.16	851786.1	5.00	1.94E+5	1.91E-2
E10	5215		2606.6	40.74	35809.4	4.00	2.02E+5	1.98E-2
5215	E10A		1199.3	122.37	107396.5	4.00	9.29E+4	2.12E-2
E10A	5219		190.3	82.88	72733.4	2.00	2.95E+4	2.69E-2
E10A	5240		813.1	162.69	142831.5	3.00	8.40E+4	2.23E-2
E9	5252		20494.0	83.02	73003.5	10.00	6.35E+5	1.58E-2
5252	HOSP		16965.1	498.44	437825.6	10.00	5.26E+5	1.60E-2
5252	E11		1381.0	309.34	271868.3	3.00	1.43E+5	2.13E-2
E11	5275		595.5	35.42	31136.9	2.00	9.22E+4	2.36E-2
E11	5276		589.6	23.62	20761.7	2.00	9.13E+4	2.36E-2
5252	E12		1400.9	548.64	481054.0	5.00	8.68E+4	2.08E-2
E12	E13		1053.9	122.83	107707.5	4.00	8.16E+4	2.15E-2
E13	5256		377.4	32.69	28660.9	3.00	3.90E+4	2.47E-2
E13	5257		260.7	65.37	57321.8	3.00	2.69E+4	2.62E-2
E13	5258		260.7	65.37	57321.8	3.00	2.69E+4	2.62E-2

COMPUTED TRAP LOSSES

10 percent trap leakage rate

Trap Steam Losses	Trap Heat Losses
506.2 lbs/hr	602750.4 Btus/hr

Ft Dix Dist Sys
CHP 5426

SYSTEM MASS FLOWS

(1)	Steam to loads:	27204. lbm/hr
(2)	Steam condensed in pipes:	10195. lbm/hr
(3)	Steam condensed in vaults:	0. lbm/hr
(4)	Steam lost to trap leakage:	506. lbm/hr
(5)	Total steam plant output:	37905. lbm/hr

(6)	Pipe and vault condensate returned:	3058. lbm/hr
(7)	Load condensate returned:	0. lbm/hr
(8)	Total condensate returned:	3058. lbm/hr

SYSTEM HEAT LOSSES AND DISTRIBUTION EFFICIENCY

(M = Million)

(1)	Total pipe conduction heat losses:	8.949 MBtus/hr	59.74 %
(2)	Total pipe condensate heat losses:	2.243 MBtus/hr	14.98 %
(3)	Total load condensate heat losses:	3.184 MBtus/hr	21.26 %
(4)	Total vault conduction heat losses:	.000 MBtus/hr	.00 %
(5)	Total vault condensate heat losses:	.000 MBtus/hr	.00 %
(6)	Total trap heat losses:	.603 MBtus/hr	4.02 %
(7)	Total heat losses:	14.979 MBtus/hr	100.00 %
(8)	Total heat to loads:	29.206 MBtus/hr	
(9)	Total heat input to supply:	45.145 MBtus/hr	
(10)	Total heat returned to plant:	.000 MBtus/hr	
(11)	Net heat input from plant:	45.145 MBtus/hr	

DISTRIBUTION EFFICIENCY:66.8%[1.0-(7)/(11)]

Appendix B: Monthly Electrical Loads and Charges, Calendar Year 1992

Table B1 lists the full spreadsheet tabulation of the electrical costs and usage at Fort Dix from January to December 1992. Meters were read on or about the 25th of each month.

Table B1. Electrical load, demand, and costs at Fort Dix, Cy92.

Month	On-Peak (KWH)	Off-Peak (KWH)	Total (KWH)	Deman d (KW)	MW	On Peak Charge	Off Peak Charge	Demand Charge	KVAR Carge	Excess KVA Carge	Line and xfmr Charge	Customer Charge	Rate Adj. Misc.	Total	Ave Cost Per KWH	CDD
Jan 1992	2292000	3300000	5592000	10464	10.5	$154,572	$171,798	$98,676						$425,046	$0.0760	0
Feb 1992	2484000	3840000	6324000	10272	10.3	$182,077	$198,067	$85,360						$465,505	$0.0736	0
Mar 1992	2328000	3300000	5628000	10157	10.2	$170,642	$170,214	$84,403						$425,259	$0.0756	7
Apr 1992	2280000	3180000	5460000	9542.4	9.5	$167,124	$164,024	$79,297						$410,446	$0.0752	26
May 1992	2136000	3264000	5400000	9792	9.8	$156,569	$168,357	$81,372	$2,135		$1,055	$143	($5,670)	$403,960	$0.0748	143
Jun 1992	2220000	3084000	5304000	11059	11.1	$162,726	$159,073	$101,966	$2,821		$1,055	$143	($5,569)	$422,215	$0.0796	305
Jul 1992	3072000	4428000	7500000	15440	15.4	$225,178	$228,396	$142,357	$2,821		$1,055	$143	($7,875)	$592,075	$0.0789	204
Aug 1992	2388000	3300000	5688000	14760	14.8	$175,040	$170,214	$136,087		$1,351	$1,055	$143	($5,972)	$477,918	$0.0840	120
Sep 1992	2040000	2964000	5004000	11424	11.4	$149,532	$152,883	$105,329	$3,144		$1,055	$143	($5,254)	$406,832	$0.0813	6
Oct 1992	1992000	3120000	5112000	8755.2	8.8	$146,014	$160,930	$72,756	$2,279		$1,055	$143	($5,368)	$377,808	$0.0739	0
Nov 1992	2004000	2904000	4908000	8620.8	8.6	$146,893	$149,788	$71,639		$920	$429	$192	($5,153)	$364,707	$0.0743	0
Dec 1992	2232000	3408000	5640000	8966.4	9.0	$163,606	$175,785	$74,511	$2,158		$1,055	$143	($5,922)	$411,335	$0.0729	
Totals	27468000	40092000	67560000	129253	129.253	$1,999,973	$2,069,529	$1,133,752	$15,358	$2,271	$7,815	$1,191	($46,784)	$5,183,106		
Ave.	2289000	3341000	5630000	10771	10.7711	$166,664	$172,461	$94,479	$2,560	$1,136	$977	$149	($5,848)	$431,926	$0.0767	
S. Ave	2430000	3444000	5874000	13171	13.1708	$178,119	$177,642	$121,435	$2,929	$1,351	$1,055	$143	($6,168)	$474,760	$0.0810	
W. Ave	2218500	3289500	5508000	9571.2	9.5712	$160,937	$169,870	$81,002	$2,190	$920	$899	$155	($5,528)	$410,508	$0.0745	

Appendix C: Energy Usage Projection for a Normal Weather Year

Table C1 contains the full spreadsheet analysis to estimate energy usage and economic costs expected at Fort Dix during a normal heating-degree-day and cooling-degree-day year. Actual performance will vary.

Table C1. Energy plant production and electrical usage projections for a normal HDD and CDD year for Fort Dix.

Month	HDD (monthly)	CDD (monthly)	Total Thermal Production (lbs/hr) minus laundry	Total Thermal Production (MBtu/hr) minus laundry	HEATLOAD and SHDP Model (MBTU/hr)	HEATLOAD SHDP Montly Fuel Use (76% eff) (MBtu/mon)	#6 Oil Use (logged data) (MBtu/hr)	Montly Fuel Use (60% eff) (MBtu/mon)	Thermal Production (60% ave logged eff) (MBtu/hr)
Jan	1011.2	0.0	76,461	76.973	135.859	132,998.815	127.385	94,774.283	76.516
Feb	859.6	0.0	72,950	73.434	132.112	117,857.602	121.638	82,470.663	73.064
Mar	670.7	1.8	58,873	59.249	117.089	114,624.347	98.600	73,358.634	59.226
Apr	380.1	11.8	44,521	44.787	101.774	96,417.185	75.113	54,081.120	45.118
May	125.6	66.6	30,724	30.884	87.051	85,218.365	52.534	39,085.630	31.556
Jun	14.8	221.6	25,026	25.142	80.970	76,708.288	43.209	31,110.180	25.954
Jul	0.7	353.9	24,270	24.381	80.164	78,476.084	41.972	31,227.426	25.212
Aug	2.7	320.7	24,374	24.485	80.274	78,583.989	42.141	31,353.190	25.313
Sep	45.4	155.9	26,657	26.786	82.711	78,357.441	45.878	33,032.285	27.558
Oct	241.1	26.7	36,686	36.892	93.413	91,446.297	62.291	46,344.355	37.416
Nov	498.3	3.2	50,827	51.141	108.503	102,792.587	85.433	61,511.724	51.317
Dec	847.8	0.1	68,022	68.469	126.854	124,182.955	113.574	84,499.299	68.221
Total						1,177,664		662,849	
Ave									

Table C1. (Cont'd).

Month	Projected #6 Fuel Cost (60% eff.) ($/hr)	Monthly Fuel Bill #6 Oil (60% eff.)	#6 Oil Use (76% eff.) (MBtu/hr)	Monthly Fuel Use (76% eff) (MBtu/mon)	Projected #6 Fuel Cost (76% eff.) ($/hr)	Monthly Fuel Bill #6 Oil (76% eff.)	Monthly savings from plant improv.	Projected Gas Fuel Cost (60% eff.) ($/hr)	Monthly Fuel Bill Nat Gas (60% eff.)	Projected Nat Gas Fuel Cost (76% eff.) ($/hr)
Jan	$561.50	$417,755.56	100.68	74,905.353	$443.78	$330,175.31	$87,580.25	$717	$533,769	$567.03
Feb	$536.17	$363,522.44	96.14	65,181.123	$423.76	$287,311.87	$76,210.57	$685	$464,475	$541.45
Mar	$434.62	$323,357.52	77.93	57,979.382	$343.50	$255,567.32	$67,790.20	$555	$413,156	$438.90
Apr	$331.09	$238,384.17	59.37	42,743.298	$261.68	$188,408.18	$49,975.99	$423	$304,585	$334.35
May	$231.57	$172,285.55	41.52	30,891.533	$183.02	$136,166.79	$36,118.76	$296	$220,130	$233.85
Jun	$190.46	$137,130.56	34.15	24,588.094	$150.53	$108,381.86	$28,748.70	$243	$175,213	$192.33
Jul	$185.01	$137,647.37	33.17	24,680.760	$146.22	$108,790.32	$28,857.05	$236	$175,873	$186.83
Aug	$185.76	$138,201.73	33.31	24,780.159	$146.81	$109,228.46	$28,973.26	$237	$176,581	$187.58
Sep	$202.23	$145,603.01	36.26	26,107.240	$159.83	$115,078.10	$30,524.90	$258	$186,038	$204.22
Oct	$274.57	$204,281.28	49.23	36,628.505	$217.01	$161,454.79	$42,826.50	$351	$261,011	$277.27
Nov	$376.58	$271,137.53	67.52	48,616.115	$297.63	$214,294.97	$56,842.56	$481	$346,434	$380.29
Dec	$500.62	$372,464.46	89.76	66,784.466	$395.67	$294,379.25	$78,085.21	$640	$475,900	$505.55
Total		$2,921,771.17		523,886		$2,309,237.22	$612,533.95		$3,733,164	
Ave										

Table C1. (Cont'd).

Month	Monthly Fuel Bill Nat Gas (76% eff.)	Monthly savings from plant improv.	CHP 5881 (MBtu/hr)	CHP 5426 (MBtu/hr)	CHP 5324 Laundry (MBtu/hr)	Off-Peak Load (KWHr)	On-Peak Load (KWHr)	Demand (KW)	Off-Peak Cost	On-Peak Cost	Demand Charge	Total Elect Charge
Jan	$421,866.95	$111,901.81	35.624	67.423	6.043	3300000	2200000	9982.7	$206,448	$159,412	$82,956	$448,816
Feb	$367,100.08	$97,374.69	34.684	65.167	5.848	3300000	2200000	9982.7	$206,448	$159,412	$82,956	$448,816
Mar	$326,539.88	$86,615.94	30.916	56.119	5.065	3301881.9	2201881.9	10003.699	$206,566	$159,548	$83,131	$449,245
Apr	$240,730.25	$63,854.61	27.075	46.894	4.267	3312336.9	2212336.9	10120.359	$207,220	$160,306	$84,100	$451,626
May	$173,981.11	$46,149.15	23.383	38.027	3.500	3369595.45	2269595.45	10759.267	$210,802	$164,455	$99,200	$474,457
Jun	$138,480.15	$36,732.39	21.857	34.365	3.183	3531682.8	2431682.8	12567.886	$220,942	$176,200	$115,876	$513,018
Jul	$139,002.04	$36,870.82	21.655	33.879	3.141	3669967.6	2569967.6	14110.909	$229,593	$186,220	$130,103	$545,916
Aug	$139,561.86	$37,019.31	21.683	33.946	3.147	3635257	2535257	13723.597	$227,422	$183,705	$126,532	$537,658
Sep	$147,035.98	$39,001.85	22.294	35.413	3.274	3463028.3	2363028.3	11801.818	$216,647	$171,225	$108,813	$496,685
Oct	$206,291.74	$54,719.67	24.978	41.859	3.832	3327914.85	2227914.85	10294.182	$208,194	$161,435	$85,545	$455,174
Nov	$273,805.96	$72,628.07	28.763	50.948	4.618	3303345.6	2203345.6	10020.031	$206,657	$159,654	$83,266	$449,578
Dec	$376,130.11	$99,769.94	33.365	62.000	5.574	3300104.55	2200104.55	9983.8666	$206,455	$159,420	$82,966	$448,840
Total	$2,950,526.11	$782,638.26				40815115	27615115	133351	$2,553,394	$2,000,991	$1,165,444	$5,719,829
Ave												$0.0836

Appendix D: Energy Plant Modification and Improvement Work Items

Mike Brewer (USACERL) and Charles Schmidt, Schmidt Associates Inc. (SAI) visited CHP 5426, CHP 5881, and CHP 5324 at Fort Dix on 20 September 1994 to develop a list of short range work items to improve the efficiency of the central energy system. The short list has been refined based on the observations:

Code/Safety Items

CHP 5881–Relief valves on the HP steam to 5# line need to be vented outside the building (Figure D1).

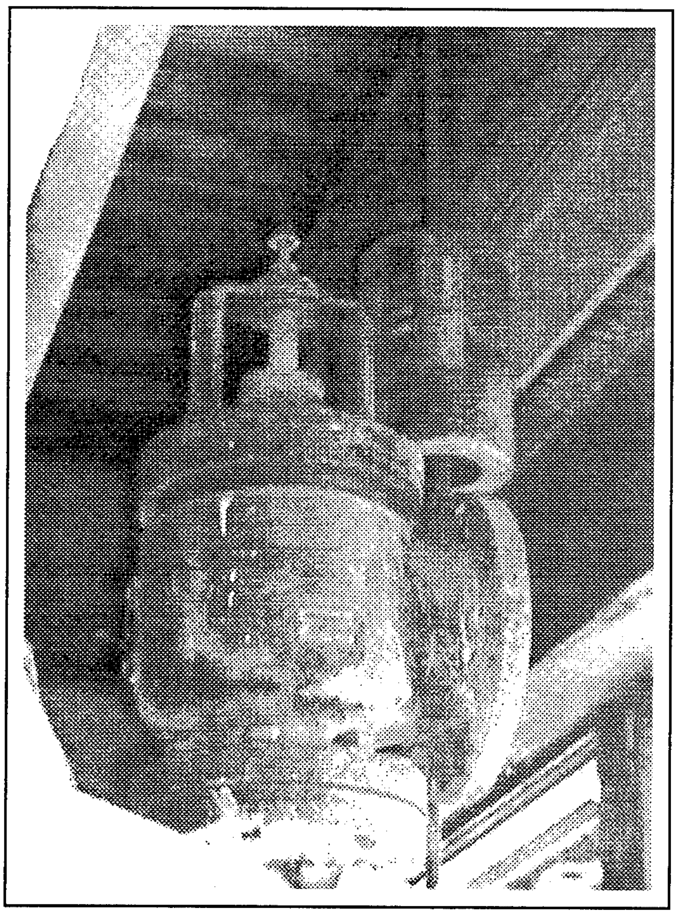

Figure D1. CHP 5881 HP/LP steam line relief.

Engineering/Economic Items

CHP 5324 (Laundry)–Instrumentation upgrade (Nat gas, Steam Flow, Flue Gas Temp)

CHP 5324 (Laundry)–Feedwater Reg Valves needed instead of cycling feed pumps

CHP 5881–PRVs for HP/LP line to DA tank need repair

CHP 5426–Erie City Iron Works boilers heat exchange is poor (650 °F flue gas temp on boiler recorder); suspect multiple causes, shifted baffles, low burner location, high excess air, windbox giving nonuniform air flow.

CHP 5881–Boiler refractory damaged, #2 boiler below burners

CHP 5426–Boiler refractory damaged (repair being scheduled as of November 1994)

Plant Capacity

CHP 5324 (Laundry)–Carrying very low loads

CHP 5252 usage should be minimized or small boiler installed

Other Comments About Plants

CHP 5324 (Laundry)

- Recommend a small summer boiler
- A few small casing leaks
- Good combustion efficiency from boiler when loaded (80 percent)
- Todd/Coen burner setup is good but FD fan ducting needs a longer run to get more uniform air flow through the register.

CHP 5881

- Cavitation on feedpumps may have been caused by deposits in feedline (Figure D2)
- New multiport valve being installed in HP/LP steamline
- Boiler casing and buckstays warped (#2 boiler is the worst) (Figure D3)
- ECIP economizer location might need close attention
- Instrumentation performance not examined since plant shutdown

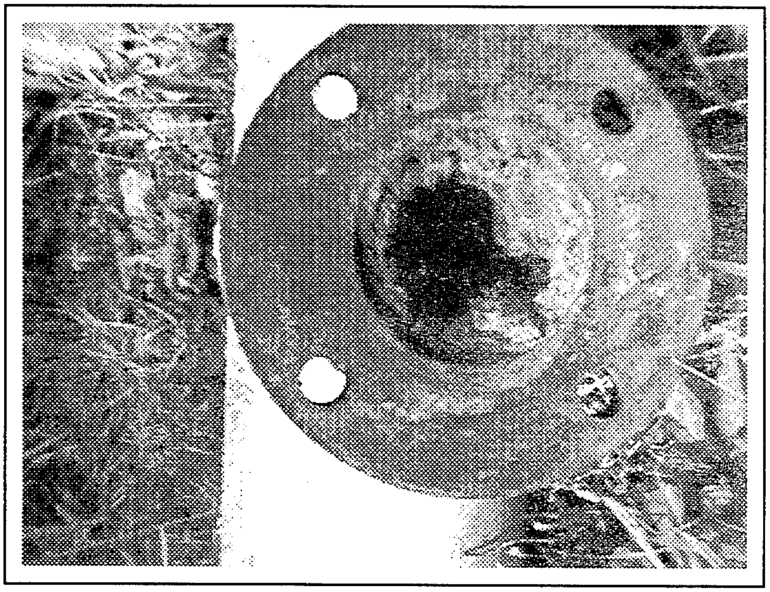

Figure D2. Feed pump suction line deposits, CHP 5881.

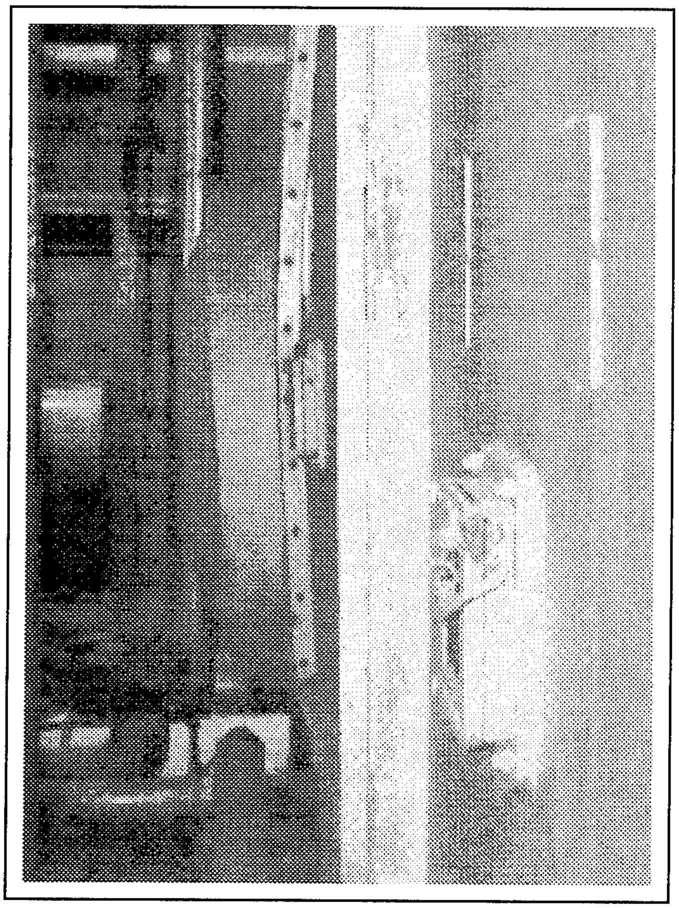

Figure D3. Casing on Boiler No. 2, CHP 5881.

CHP 5426

- Refractory is being overheated, possibly past its fusion temp
- O_2 sample port which would not interfere with boiler controls but would be close to the boiler outlet (i.e., before the induced draft fan) would help verify installed instrumentation
- Conversion to gas may intensify damage to refractory, especially if low NOx burner attempted
- Coal conversion burner location normally 5 feet above old coal grate
- Boiler #2 casing bulged

HRI

Plant personnel indicate enough refuse received to steam one boiler at 7,000 lb/hr 24 hr/day, 7 days a week.

Appendix E: CHP 5426 Plant Visit Observations 14-16 November 1994

USACERL and SAI conducted a site visit to CHP 5426, Fort Dix, NJ on 14-16 November 1994. Operational tests of Boilers #1 and #3 were conducted measuring O_2, CO, CO_2, NOx, and SOx, and furnace pressure and boiler outlet temperatures under low, medium, and high fire conditions. An internal inspection of Boiler #2 was conducted including a visual furnace inspection, UT thickness of 22 tubes 4-1/2 feet off of the furnace floor, visual inspection of furnace and generating tube baffle, visual inspection of left water wall header (watersides), and visual inspection of water wall tube inlet (waterside)

The following observations were recorded pertaining to boiler #2:

- Refractory damage on right, left and target walls
- Burner refractory damage (Figure E1, Figure E2)
- Gas burner ring cracks between orifices (Figure E3)
- Hard metallic deposits on fireside of tubes (Figure E4)
- Sulfur-like deposits on fireside of tubes
- Significant flue gas bypass path underneath mud drum (Figure E5)
- Tube ties broken/missing on left and right furnace wall, tubes moved out of alignment from furnace wall 2 to 6 in.
- Exposed waterwall header left side
- Major casing leaks (daylight showing)
- Generating tube baffles satisfactory condition, only 3 minor holes
- Large amounts of soft ash in generating tube banks, soot blowers appears to be ineffective
- Target wall baffles need rebuilding
- Expansion joints needed in front wall and target wall, solid mortar used instead of mineral wool packing, refractory shifted out of place (Figure E6).
- Outside of backwall refractory shifted out of place, solid mortar used instead of mineral wool packing
- Hard red scale deposits in left waterwall header and at water wall tube entrance, thickness approx. 0.1 in. (Figure E7).

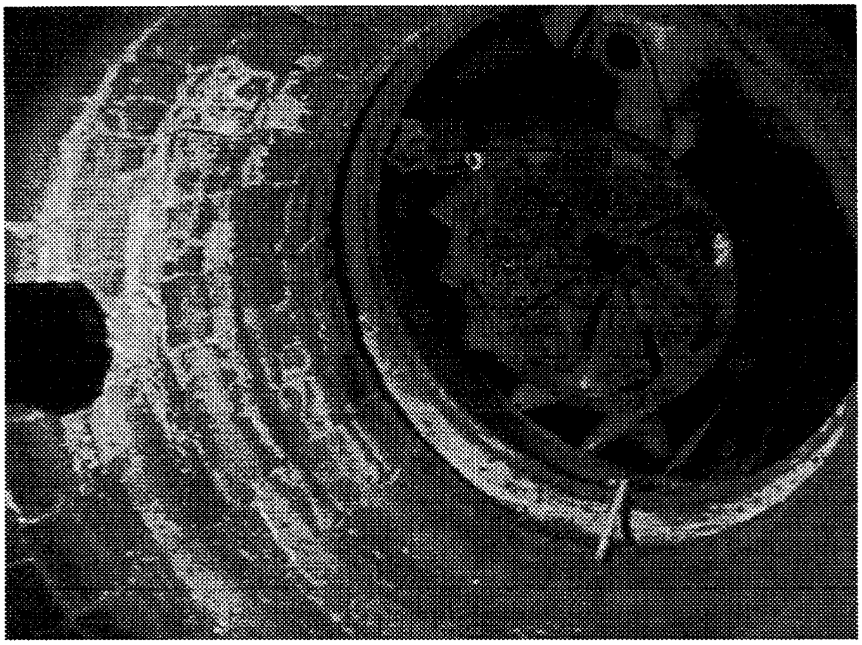

Figure E1. Burner refractory damage.

Figure E2. Closeup of burner refractory damage.

Figure E3. Gas burner ring with cracks between orifices.

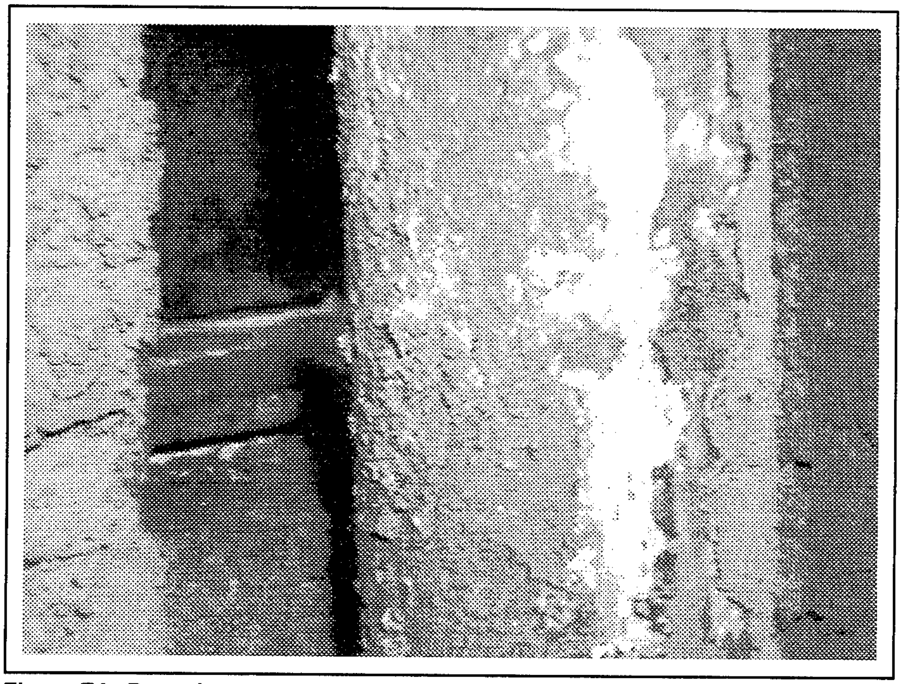

Figure E4. Deposits on watertube firesides.

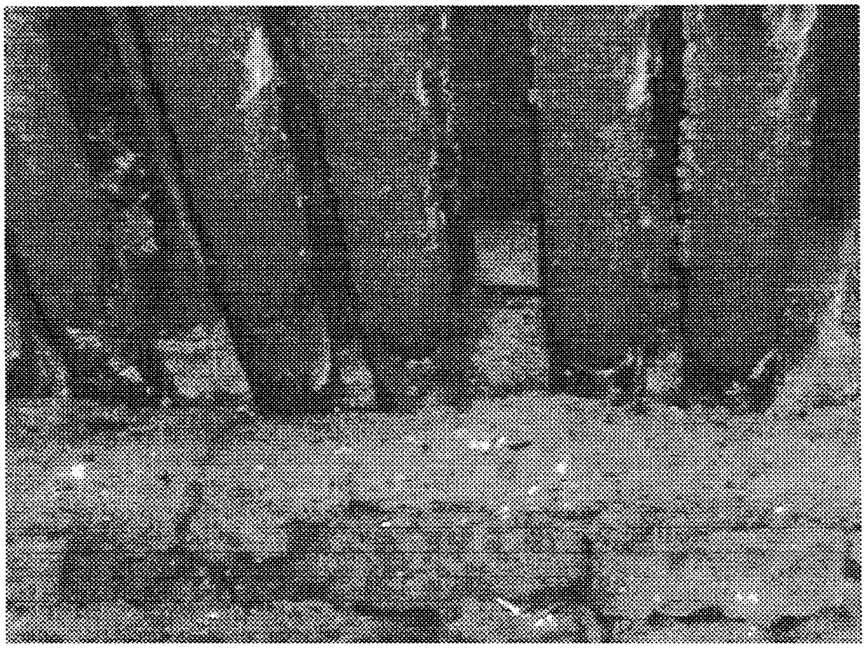

Figure E5. Refractory damage under mud drum (flue gas bypass).

Figure E6. Shifted refactory on front wall.

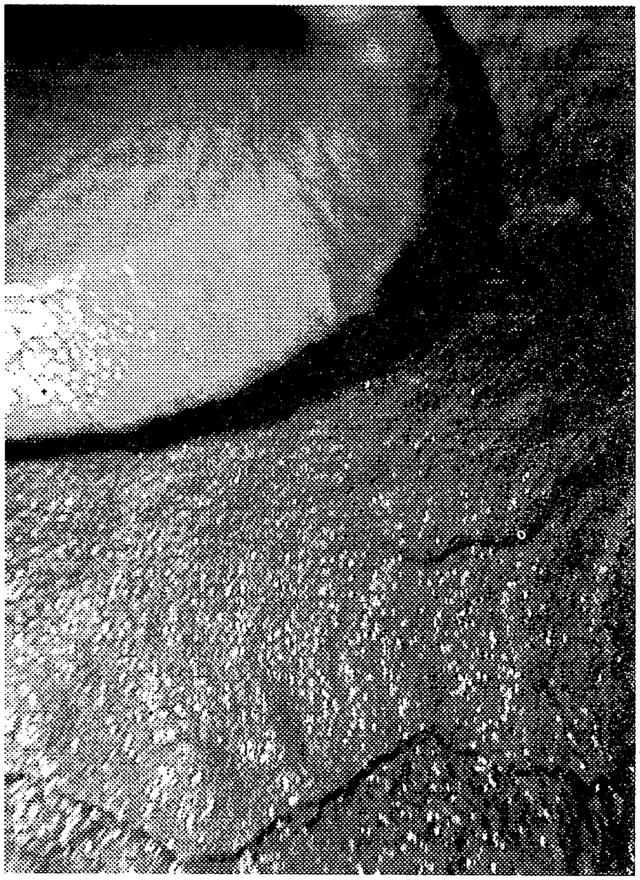

Figure E7. Hard red scale in water wall header and watertube inlet.

The following observations were made pertaining to the operational tests of boilers #1 and #3:

- Draft control in not operating effectively, Variable Speed Drive (VSD) ID fans do not track with firing rate changes when in auto control
- Very high stack gas temperatures (890 °F, dual thermocouple).
- Very high O_2 reading in stack gas
- Boiler #3 O_2, Boiler Outlet Temperature and Steam Flow instrumentation is out of commission
- Boiler #1 O_2, Boiler Outlet Temperature out of calibration
- High makeup rate (85 percent)

Other general observations about the plant:

- Platforms and ladders around boilers need modifications to meet current safety standards
- Recommended location of boiler feed water reg. valve is on the operating floor instead of up near the steam drum
- DA tank is running too cold (212 °F) for 7 to 12 psig operating pressure

Appendix F: Schmidt and Associates, Inc. Plant Assessment

Fort Dix Boiler #2, CHP 5426, External Inspection

General Note

All comments with respect to right or left on boiler is from standing in front of the boiler in the firing aisle and your right hand is called the right hand side of the boiler and your left hand is called the left hand side of the boiler for location.

Upper Left Explosion Door

At the time of manufacturing these boilers under the ASME Code, explosion doors were installed on boilers which consist of a cast iron frame and cast iron door. The cast iron door is at a 70 degrees angle from the horizontal. The intent of this angle is to keep the door closed under normal operating conditions by the weight of the cast iron door and it is hinged at the top to the frame. The problem with these doors are that if an explosion occurs, the cast iron hinge breaks and the entire door or parts of the door will become a flying missile that can greatly injure someone. On this type of a boiler, the very weak seam or weak construction of the boiler is where the furnace roof tubes and the furnace roof joins into the steam drum. If an explosion occur, the weak point of the casing will fail causing the insulation and refractory tile to blow vertically and generally results in very few people being injured. The casing normally keeps the refractory material from becoming flying objects and it just simply opens this casing seam between the drum and the roof casing the entire width of the boiler. This is a very safe place, in my opinion, to have a boiler open up during an explosion. I have been brought in on deaths of people due to the fact that the cast iron explosion doors have become missiles and caused the loss of human life. For the correction of this issue, I refer you back to the original boiler manufacturer, Erie City Iron Works (Zurn Industries), for their recommendations of the elimination of the explosion door.

Performance Testing

Boiler No. 3 Steam Load Test

Performance testing of the existing Boiler No. 3, (design rating—50,000 #/Hour maximum steam load), was conducted based on normal operating conditions. Attached is a list of those parameters which were monitored. Instrumentation devices were brought to the field for accurate measurement of both flue gas temperature and content of oxygen, which has direct relationship to excess air. There were three firing rates tested, (high fire, approximately 50 percent load and minimum firing rate.) Minimum firing is not normally done by these boilers, only because they would normally take boilers offline and produce steam so that the boilers are normally running from 50 percent steam load up to high fire.

Abnormally high flue gas temperatures were measured at the boiler outlet, both left and right side. These temperatures were approximately 400 °F too high. The excess airs measurements at high fire were abnormally high at 69 percent, (normal excess air is 20 percent).

At high fire, we were able to achieve 41,178 #/hour steam flow based upon the oil flow meter because the steam flow meter was not functioning on the day of our test. At medium load, we operated the unit at 23,231 #/hour, slightly less than 50 percent load. The low fire rate was conducted at 6,739 #/hour. At high fire, the boiler was 66.57 percent efficient. It should have been at 83.6 percent which indicates an efficiency waste of 17 percent. The same percentage of wasted efficiency was found at 50 percent fire. Of the fuel consumed in this boiler plant, this boiler is typically operating in the 50 percent range annually and is losing approximately 17 percent of the total fuel input.

Boiler No. 1 Steam Load Test

Boiler No. 1, which is an identical unit to Boiler No. 3 above, was load tested at 50 percent firing rate and two high fire conditions. The 50 percent load firing efficiency rate for Boiler No. 1 was more efficient than Boiler No. 3 by approximately 6 percent because the boiler exit flue gas temperature on this unit is 683 °F at the 50 percent firing rate rather than 724 °F, (a 40 °F drop in flue gas temperature which increased this boiler efficiency by approximately 1 percent). The remainder of the efficiency improvement of approximately 5 percent was due to the lower excess air on Boiler No. 1 which was 74 percent as compared to Boiler No. 3 which ran 113 percent excess air.

Two tests were conducted at high fire, the first test conducted was at a furnace pressure of –0.06 in. of water where the boiler operated at 75 percent efficiency vs. the second test which is more of the normal operating condition with the furnace at –0.1 in. of furnace draft. The excess airs measurement at –0.11 was 51.78 percent excess air as compared to the furnace draft condition of –0.06 with an excess air measurement of 21.28 percent. As the excess air decreased, there was a corresponding reduced quantity of mass flue gas flow, resulting in better heat transfer, and lower flue gas temperatures. The flue gas temperature at the normal condition of –0.11 in. of water averaged 904 °F compared to the flue gas temperature at the lower furnace static pressure of –0.06 of 815 °F. Correspondingly, the efficiency improvement was from 68 percent to 75 percent or approximately 7 percent increase in overall boiler efficiency. For all practical purposes, the steam loads were the same, although at the lower furnace draft the steam flow actually increased by 1,000 #/hour with considerably less oil flow usage. Our normal predicted efficiency for Boiler No. 1 would be the same as listed on the sheet for Boiler No. 3. At high fire, we would predict that Boiler No. 1 would be at approximately 83.6 percent efficiency vs. the tested of 68.38 percent or an efficiency improvement of 15 percent.

Conclusion

These boilers have major problems. Flue gas temperatures above 500 °F at high fire for these boilers is extremely detrimental to the boilers, the ductwork after it leaves the boilers and the induced draft fans. Failure of the induced draft fans may occur due to carbon steel operating at such elevated temperatures. The fuel consumption of this boiler plant could be reduced between 13 percent to 17 percent and with an average of a 15 percent annual fuel savings. Before any work is contemplated with economizers, (typical 3 to 4 percent plant efficiency improvement), it is highly recommended that the problem with the elevated flue gas temperatures be solved. Please provide the flue gas temperature, oxygen and fuel flow information to the economizer manufacturer to ensure steaming economizer condition is avoided.

Recommendations

1. The exit flue gas temperature at the outlet of the boiler—this is where the flue gas exits the upper rear of the boiler. Normal flue temperatures for this size unit should be in the 360 to 470 °F range, from low load to high load. In Boiler No. 3, the range was found from 528 to 897 °F with some instantaneous readings going over 900 °F. Depending upon the boiler which was performance tested (Boiler No. 3 or Boiler No. 1), approximately 15 percent of the fuel input to this plant is wasted

based on two of the three boilers being tested. This is an unbelievably large quantity of fuel. The reasons for the high flue gas temperature are:

a. Leaking of a portion of the flue gas flow directly from the furnace below the mud drum. There is a major leak of short circuiting which is occurring at the top of the rear furnace bridge wall (See Sketch No. 1).
b. The soot blowers are not performing correctly. There was approximately 1/4 in. of soft completely combusted fly ash over the entire generating tubes.
c. The existing furnace draft control of the variable speed induced draft fan is not functioning.
d. There was some fireside hard scale, i.e., metallic like, and
e. There was some waterside hard scale approximately 0.1 in. thick. The above order is suggested in the priority of repair.

2. The refractory condition of Boiler No. 2, which was offline and physically inspected, is in unacceptable condition. All furnace refractory walls and roof must be replaced along with refractory walls below sidewall headers, floor and rear furnace bridge wall. Over the years, the repairs that have been made on this unit have not included the detail expansion joints that are required. The refractory in this furnace will reach temperatures above 1800 °F, and expansion joints must be designed to account for the 1750 °F temperature change. The tube ties, which are a physical tie between the tube and the structural buckstay around the furnace, have failed and some of the tubes are falling into the furnace and are no longer in alignment. This misalignment is 3 to 4 tube diameters. The refractory throats of the burners have been damaged. There should also be installed a circumferential expansion joint type for the burner refractory. As the burner throat heats up to 2800 °F, the refractory expands. If there is not room for thermal expansion, the refractory will be damaged again. Existing natural gas burner rings in the burner have very small orifice holes in them. Between these holes there are cracks in the existing gas ring pipe which will provide very poor natural gas distribution into the flame. If these units are converted to natural gas using the current rings, a dangerous condition will occur. These must be replaced. There is a water wall exposed on the left hand side of Boiler No. 2 directly to the radiant heat of the flame. This is unacceptable. If steam bubbles start to form in the sidewall header, (since it is not protected by refractory) nucleate boiling in the furnace tubes will change to film boiling and there will be tube and header failure. It is probably in good condition since the burners do not have the capacity to reach 50,000 #/Steam Per Hour. It is probable that (tube and header failure) would have already occurred if the boilers were continually at high fire. From the inside of the furnace, it is possible to see daylight inside the furnace due to refractory damage. Where the water wall headers pass through the rear wall, there are major leaks in

refractory. This complete refractory setting will have to be replaced. Estimated cost per boiler is from $70,000 to $100,000 per boiler.

It is recommended to consult Erie City Iron Works (Zurn Industries), the original boiler manufacturer, and get information to install adequate expansion joints in all refractory walls. Particular attention must be paid to be refractory walls below the side wall headers.

The furnace right and left side wall, the front wall and bridge wall—all need expansion joints because this refractory material will come up to almost 1800 °F under full operating load. The boiler must be brought up to this condition over a 5 hour time period. An adequate expansion joint must be allowed and designed into the unit. The current boilers were furnished with square edge tile. This is very poor because any shifting of the tile will cause the tile will fail. This refractory should be ship lap tile. There is no other acceptable design. The bridge wall and the refractory walls below the side wall headers will have to be made out of standard No. 1 fire brick, however, staggered joints and expansion joints must be installed. Please note that these units are running at 70 percent excess air when they should be running at 20 percent excess air at full load. A large percentage of this air is not being brought in through the burner, it is being brought in through air infiltration through the poor refractory walls.

3. Generation Section of boiler is defined as that section of Boiler No. 2 with massive tubes between the steam drum and the mud drum. Physical inspection was made of the baffles in this area. The refractory baffles are in excellent condition. There are three very minor holes which will not contribute to the massive flue gas temperature increase at boiler outlet. These holes should be fixed as they are quite visible. The baffles are in alignment and the tubes are in alignment but the soot blowers in this section of the boiler are not doing an adequate job because of the 1/4 in. of soft gray fly ash that is adhering to the tubes and decreasing heat transfer and contributing to the higher flue gas temperature.

4. On the upper left hand side of the Boiler No. 2 outside casing, there is an explosion door. I consider these extremely unsafe even though they were standard in the ASME Code for boilers at the time these boilers were manufactured. My concern for this explosion door is the fact that it is cast iron with a cast iron hinge, and if an explosion occurs, rather than the door swinging open, it becomes a flying missile. I refer you back to Erie City Iron Works (Zurn) for their recommendation on elimination of this explosion door. This is definitely a safety issue.

5. It is amazing that the exterior casing of these boilers (Nos. 1, 2 & 3) appear to be in good condition because of the amount of overheating that has occurred due to the lack of refractory and the condition of the refractory on the interior of the furnace. The good news is the excellent conditions of the main structural I-beams and channels that are called buckstays, that provide the belly bands around the boiler to keep it together. These main structural buckstays are also in alignment and are straight. This boiler is well worth saving because of the conditions of the buckstays.

6. Waterside—Inspected the left hand hole header on Boiler No. 2 and found there to be hard scale up to 0.1 in. thickness that has dropped down from the furnace tubes. This scale thickness should not be there. The bulk of this hardness that is getting back into the boilers is probably from the condensate system. The typical source is from domestic hot waters leaking hard domestic water directly into the condensate side of heat exchangers.

7. The furnace draft on Boiler No. 1 and Boiler No. 3; The existing controller and variable speed ID fan are not controlling furnace draft to –0.10. They are running the furnace draft up to –0.50, i.e., five times too much draft, and pulling air in through this leaky setting and destroying the efficiency of the boiler as well as increasing boiler exit flue gas temperatures.

Appendix G: CHP 5426 Thermal Performance Improvement Work List

Improve Heat Transfer of Boilers No. 1, 2 and 3

Repair ID fan controls–The variable speed drive (VSD) induced draft fans should be able to control furnace draft in the range of -0.8 to -1.2 inches WC. The Barber-Coleman boiler controls are either not sending the correct signal or the signal from the Barber-Coleman controller is being corrupted with line noise. As a result, the furnace draft is controlled at greater than -5.0 inches WC to ensure positive draft will not occur during high firing rates. The excessive draft draws the flue gases through the boiler so fast that the gases do not have sufficient residence time to transfer energy to the water tubes.

Acid wash fireside of boiler tubes–The fireside of the boiler tubes have tenacious deposits which should be removed to improve heat transfer.

Acid clean waterside of boiler tubes–The waterside of the boiler tubes appear to have a hard red deposit. Condensate system metals and water hardness deposits are reducing the heat transfer of the tubes.

Repair refractory and repair tube ties–The tube ties are missing or broken in the boiler furnace. Technical documentation was procured from Zurn Industries, Energy Division to establish description of original construction. The prints were delivered to Fort Dix engineering staff. The refractory on three of the four walls needs major repair. To achieve design service life of the refractory the appropriate expansion joints need to be utilized. Additionally, the burner cone refractory need to be replaced.

Improve boiler auxiliaries

Verify soot blowers properly sized for reduced pressure operation–Since the boiler is operating at less than the design pressure of 125 psig, the orifices in the soot blowers may not be sized to achieve effective soot blowing.

Inspect and repair deareating tank internals–The deareating (DA) tank is running too cold for a vessel pressure of 7-15 psig. Inadequate heat transfer is occurring in the DA tank. Since the tank was running at 212 °F, it is possible that the dissolved O_2 level in the feedwater leaving the DA tank could be as high as 3 ppm instead of the design 0.05 ppm. Additionally, the best O2 stripping action occurs when the temperature of the feedwater increases by at least 50 deg F when entering the DA tank. It is possible the trays have deposits in them or the feedwater sprays are not atomizing the feedwater adequately.

Repair boiler instrumentation–All of the inoperative boiler instruments should be repaired and the operating instruments should be calibrated. A gauge and instrument calibration program should be initiated if not already in place.

Repair / Replace gas burner ring assemblies–The gas rings have cracks between the orifices. When installing gas service to the burners, the rings should be repaired or replaced with gas spuds. The boiler manufacturer (Zurn Industries) is able to send a field technician to assist in the burner selection. Additionally, NOx production should be a considered in burner selection as more stringent air standards may be applicable to boilers at Fort Dix.

Other Items to Improve Industrial Hygiene/Ergonomics

Move feedwater regulating valves to operating floor–Currently the feedwater regulating valves (FRVs) are located on the upper platforms near the steam drum. To increase access to the FRVs in case boiler operator action is required, many facilities have these valves on the operating floor.

Upgrade platforms and ladders–Several of the ladders do not have caging and some of the platforms could be increased in area and have additional railing. Although the ladders and platforms may meet the requirements for their date of construction, these improvements will help the operators perform their duties in a more effective and safe manner. Before initiating personnel access structural changes it is recommended that an industrial hygiene assessment or OSHA technical assist visit be conducted to obtain the most current regulatory advice.

Appendix H: HEATMAP Output File for 50 HDD for Steam Distribution

Note: Manual corrections had to be applied in rollup of data on last page of reports.

Heating Distribution
Node Characteristics

Dist Options
Whole Stm Sys Old Plant

Node	Consumer	Demand kBtu/hr	Flow (lb/hr)	Pressure (psig) Supply	Pressure (psig) Return	Pressure (psig) Delta	Temperature (F) Supply	Temperature (F) Return	Temperature (F) Delta
N001	Grp 2	722	713.1	104.8	79.8	25.0	228.1	180.0	48.2
N002	No connections	0	0.0	106.5	79.8	26.7	322.5	177.0	145.5
N003	No connections	0	0.0	106.0	80.1	26.0	319.4	179.6	139.8
N004	Hospital X-5226	15323	14554.1	105.6	80.3	25.3	316.4	180.0	136.5
N005	Grp 3	1063	1038.1	103.9	79.8	24.1	253.6	180.0	73.7
N006	No connections	0	0.0	106.7	79.6	27.1	323.4	175.4	148.0
N007	Grp 1	1947	1914.0	103.8	80.0	23.8	239.8	180.0	59.9
N008	No connections	0	0.0	110.9	77.2	33.7	336.9	174.2	162.7
N009	Consumer X-5418	1880	1773.4	110.8	77.3	33.6	331.8	180.0	151.9
N010	No connections	0	0.0	111.3	76.6	34.8	340.3	173.2	167.1
N011	No connections	0	0.0	106.1	78.7	27.4	301.3	176.8	124.5
N012	Grp 4	5503	5309.3	103.5	79.9	23.6	281.5	180.0	101.5
N013	No connections	0	0.0	110.6	77.3	33.3	331.3	174.3	157.0
N014	Consumer X-5411	586	562.7	110.2	77.3	32.9	291.3	180.0	111.4
N015	Grp 5	6148	5903.7	108.3	79.9	28.4	291.8	180.0	111.9
N016	No connections	0	0.0	114.1	75.5	38.6	346.5	172.4	174.1
N017	No connections	0	0.0	112.4	76.4	36.0	341.3	173.0	168.3
N018	No connections	0	0.0	112.0	76.7	35.3	332.3	173.2	159.1
N019	No connections	0	0.0	111.7	76.8	34.9	326.9	173.9	153.0
N020	Grp 8	4630	4473.5	107.9	78.5	29.4	277.9	180.0	97.9
N021	Grp 7	5078	4869.6	108.7	78.2	30.6	295.0	180.0	115.1
N022	No connections	0	0.0	111.8	76.5	35.3	338.4	174.4	164.1
N023	Grp 6.5	4490	4294.4	109.4	77.6	31.8	301.0	180.0	121.1
N024	Grp 6	5067	4849.4	108.3	78.1	30.1	299.3	180.0	119.3
N025	No connections	0	0.0	114.6	74.9	39.8	347.6	171.5	176.0
N026	Plant 5426 for scenar	-83593	-76477.7	115.0	74.7	40.3	348.1	171.5	176.6
N027	No connections	0	0.0	108.8	78.0	30.8	325.4	172.1	153.3
N028	Grp 9	2790	2674.0	106.8	78.2	28.6	296.2	180.0	116.3
N029	No connections	0	0.0	106.6	79.1	27.5	312.4	173.4	139.0
N030	Grp 10	3949	3817.3	104.6	79.9	24.7	276.8	180.0	96.8
N031	No connections	0	0.0	106.4	79.2	27.2	309.8	173.4	136.4
N032	Grp 11	844	819.5	105.4	79.2	26.2	267.0	180.0	87.1
N033	No connections	0	0.0	106.2	79.3	26.9	305.7	174.5	131.2
N034	Grp 12	3949	3823.6	104.3	80.1	24.3	273.1	180.0	93.2
N035	No connections	0	0.0	103.4	80.4	23.0	274.8	177.3	97.5
N036	Grp 13	6281	6124.2	102.1	81.9	20.2	258.1	180.0	78.1
N037	No connections	0	0.0	104.5	80.4	24.1	261.9	170.6	91.3
N038	Grp 14	3716	3669.0	102.5	81.2	21.3	229.7	180.0	49.8
N039	No connections	0	0.0	106.0	79.8	26.2	276.4	169.2	107.2
N040	Grp 15	2523	2483.0	103.2	80.2	23.0	237.2	180.0	57.2
N041	No connections	0	0.0	107.1	78.7	28.5	284.9	169.7	115.2
N042	Grp 16	3778	3701.2	105.0	79.6	25.4	247.1	180.0	67.2
N043	No connections	0	0.0	108.4	78.0	30.4	299.7	167.9	131.7
N044	Grp 17	2095	2048.6	106.5	78.3	28.2	251.3	180.0	71.3

N045	No connections	0	0.0	114.9	74.7	40.2	347.6	167.3	180.3
N046	No connections	0	0.0	114.9	74.6	40.3	324.4	39.9	284.5
N047	Plant 5881 for scenar	-44981	-41015.2	115.0	74.6	40.4	348.1	167.3	180.8

Heating Distribution Dist Options
Node Characteristics Whole Stm Sys Old Plant

Node	Consumer	Demand kBtu/hr	Flow (lb/hr)	-- Pressure (psig) -- Supply	Return	Delta	-- Temperature (F) -- Supply	Return	Delta
N048	No connections	0	0.0	114.0	75.1	38.8	339.2	170.4	168.9
N049	Grp 18	2906	2782.4	111.0	75.6	35.5	298.0	180.0	118.1
N050	No connections	0	0.0	113.7	75.3	38.4	334.0	170.3	163.7
N051	Grp 19	2095	2021.0	112.0	75.5	36.4	281.7	180.0	101.7
N052	No connections	0	0.0	111.6	77.5	34.2	316.9	172.5	144.4
N053	Grp 20	2961	2862.9	108.3	77.9	30.3	276.7	180.0	96.8
N054	Grp 21	4693	4552.0	107.6	79.3	28.4	269.5	180.0	89.6
N055	Grp 22	11282	10875.4	111.0	77.3	33.7	283.2	180.0	103.2
N056	No connections	0	0.0	113.2	75.5	37.7	335.0	163.2	171.8

TOTAL number of nodes: 56

Heating Distribution Dist Options
Pipe Characteristics Whole Stm Sys Old Plant

#	Pipe	Length (ft)	Diameter (in)	Flow (lb/hr)	Temperature (F) Upstr	Dnstr	Heat loss (kBtu/hr)	Pressure (psig) Upstr	Dnstr
1	002-001	1189.9	3.00	983.6	322.5	228.1	45.93	106.5	104.8
2	002-003	276.7	8.00	15115.2	322.5	319.4	23.21	106.5	106.0
3	002-005	1090.2	3.00	1310.9	322.5	253.6	44.32	106.5	103.9
4	003-004	253.1	8.00	14834.4	319.4	316.4	21.01	106.0	105.6
5	006-002	95.5	8.00	17682.2	323.4	322.5	8.07	106.7	106.5
6	006-007	1946.9	4.00	2185.2	323.4	239.8	90.07	106.7	103.8
7	008-006	1524.1	8.00	20149.1	336.9	323.4	132.04	110.9	106.7
8	008-009	90.4	4.00	2056.9	336.9	331.8	5.08	110.9	110.8
9	010-008	353.8	10.00	22491.3	340.3	336.9	37.10	111.3	110.9
10	010-011	1813.0	5.00	5860.7	340.3	301.3	111.73	111.3	106.1
11	010-013	436.4	6.00	7306.3	340.3	331.3	31.99	111.3	110.6
12	011-012	971.4	5.00	5582.8	301.3	281.5	53.69	106.1	103.5
13	013-014	369.7	3.00	841.4	331.3	291.3	16.42	110.6	110.2
14	013-015	1768.5	6.00	6181.4	331.3	291.8	119.17	110.6	108.3
15	016-010	1033.2	10.00	35943.0	346.5	340.3	110.05	114.1	111.3
16	016-017	586.1	8.00	20731.7	346.5	341.3	53.15	114.1	112.4
17	017-018	519.7	8.00	10461.3	341.3	332.3	46.03	112.4	112.0
18	017-022	186.0	6.00	9985.8	341.3	338.4	13.82	112.4	111.8
19	018-019	307.4	8.00	10177.5	332.3	326.9	26.58	112.0	111.7
20	019-020	1974.0	5.00	4748.4	326.9	277.9	113.80	111.7	107.9
21	019-021	1345.7	5.00	5146.7	326.9	295.0	80.08	111.7	108.7
22	022-023	1362.4	5.00	4573.6	338.4	301.0	83.66	111.8	109.4
23	022-024	1604.8	5.00	5127.8	338.4	299.3	98.24	111.8	108.3
24	025-016	232.3	12.00	56961.6	347.6	346.5	28.57	114.6	114.1
25	025-027	2349.6	8.00	19229.8	347.6	325.4	207.93	114.6	108.8
26	026-025	145.4	14.00	76477.8	348.1	347.6	19.29	114.9	114.6
27	027-028	812.3	4.00	2951.8	325.4	296.2	42.05	108.8	106.8
28	027-029	1216.5	8.00	15997.3	325.4	312.4	101.36	108.8	106.6
29	029-030	1270.5	5.00	4091.9	312.4	276.8	71.10	106.6	104.6
30	029-031	181.6	8.00	11626.1	312.4	309.8	14.72	106.6	106.4
31	031-032	560.5	3.00	1093.3	309.8	267.0	22.82	106.4	105.4
32	031-033	256.9	8.00	10253.9	309.8	305.7	20.56	106.4	106.2
33	033-034	1185.2	5.00	4097.1	305.7	273.1	65.00	106.2	104.3
34	033-035	929.4	5.00	5878.6	305.7	287.4	52.40	106.2	103.4
35	035-036	922.1	6.00	6393.1	274.8	258.1	51.96	103.4	102.1
36	035-037	1050.8	3.00	-789.0	181.3	261.9	31.45	103.4	104.5

37	037-038	1353.4	5.00	3933.0	261.9	229.7	61.45	104.5	102.5
38	037-039	694.1	5.00	-4982.4	261.9	276.4	35.02	104.5	106.0
39	039-040	1262.0	4.00	2748.9	276.4	237.2	52.47	106.0	103.2
40	039-041	555.3	6.00	-8002.4	276.4	284.9	33.22	106.0	107.1
41	041-042	1468.2	5.00	3969.5	284.9	247.1	73.09	107.1	105.0
42	041-043	1163.5	8.00	-12245.1	284.9	299.7	87.82	107.1	108.4
43	043-044	1214.7	4.00	2319.0	299.7	251.3	54.79	108.4	106.5
44	043-056	3087.1	8.00	-14839.8	299.7	335.0	255.77	108.4	113.2
45	045-047	79.7	12.00	-40731.4	347.6	348.1	9.83	114.9	115.0
46	045-048	639.1	8.00	14169.9	347.6	339.2	57.86	114.9	114.0
47	045-055	4286.2	8.00	11152.9	347.6	283.2	352.66	114.9	111.0
48	047-046	84.0	2.00	283.7	348.1	324.4	3.28	115.0	114.9
49	048-049	1158.1	4.00	3061.1	339.2	298.0	61.65	114.0	111.0
50	048-050	310.0	8.00	10824.1	339.2	334.0	27.45	114.0	113.7
51	050-051	1150.2	4.00	2298.0	334.0	281.7	58.89	113.7	112.0
52	050-052	974.4	6.00	8242.3	334.0	316.9	68.97	113.7	111.6
53	052-053	1250.3	4.00	3136.9	316.9	276.7	61.41	111.6	108.3
54	052-054	2004.2	5.00	4824.9	316.9	269.5	111.55	111.6	107.6
55	056-045	1036.0	8.00	-15122.6	335.0	347.6	93.14	113.2	114.9

TOTAL number of pipes: 56

Heating Distribution — Dist Options
Node Leakage and Losses — Whole Stm Sys Old Plant

		TO ATMOSPHERE		TO RETURN	
		Leakage	Heat Loss	Leakage	Heat Loss
#	Node	(lb/hr)	(kBtu/hr)	(lb/hr)	(kBtu/hr)
001	N001	270.52	311.69	0.00	0.00
002	N002	272.43	325.78	0.00	0.00
003	N003	280.85	335.44	0.00	0.00
004	N004	280.28	334.37	0.00	0.00
005	N005	272.78	317.48	0.00	0.00
006	N006	281.64	336.93	0.00	0.00
007	N007	271.23	313.96	0.00	0.00
008	N008	285.28	343.08	0.00	0.00
009	N009	283.55	340.32	0.00	0.00
010	N010	284.69	342.82	0.00	0.00
011	N011	277.96	329.64	0.00	0.00
012	N012	273.48	321.81	0.00	0.00
013	N013	283.47	340.16	0.00	0.00
014	N014	278.65	329.17	0.00	0.00
015	N015	277.68	328.09	0.00	0.00
016	N016	286.88	346.31	0.00	0.00
017	N017	284.51	342.74	0.00	0.00
018	N018	283.80	340.68	0.00	0.00
019	N019	282.44	338.34	0.00	0.00
020	N020	274.88	323.00	0.00	0.00
021	N021	277.11	327.82	0.00	0.00
022	N022	284.35	342.18	0.00	0.00
023	N023	279.23	331.11	0.00	0.00
024	N024	278.44	329.95	0.00	0.00
025	N025	286.33	345.79	0.00	0.00
027	N027	280.70	336.06	0.00	0.00
028	N028	277.78	328.77	0.00	0.00
029	N029	279.34	332.73	0.00	0.00
030	N030	274.51	322.43	0.00	0.00
031	N031	278.96	331.93	0.00	0.00
032	N032	273.75	320.30	0.00	0.00
033	N033	278.25	330.56	0.00	0.00
034	N034	273.50	320.77	0.00	0.00
035	N035	274.49	322.16	0.00	0.00
036	N036	268.97	313.60	0.00	0.00

037 N037	260.09	303.70	0.00	0.00
038 N038	264.00	304.37	0.00	0.00
039 N039	271.01	318.26	0.00	0.00
040 N040	265.89	307.45	0.00	0.00
041 N041	273.23	321.95	0.00	0.00
042 N042	268.22	311.37	0.00	0.00
043 N043	275.72	326.78	0.00	0.00
044 N044	270.30	314.30	0.00	0.00
045 N045	286.08	345.49	0.00	0.00
046 N046	283.72	339.54	0.00	0.00
048 N048	284.77	342.79	0.00	0.00
049 N049	278.64	330.03	0.00	0.00
050 N050	283.76	340.87	0.00	0.00
051 N051	277.03	326.01	0.00	0.00
052 N052	280.52	334.72	0.00	0.00
053 N053	273.94	321.75	0.00	0.00
054 N054	272.84	319.55	0.00	0.00
055 N055	277.42	326.67	0.00	0.00
056 N056	282.75	339.78	0.00	0.00
TOTALS:	14982.63	17753.32	0.00	N/A

Heating Distribution — Dist Options
Pipe Leakage and Losses — Whole Stm Sys Old Plant

# Pipe	SUPPLY Leakage (lb/hr)	SUPPLY Heat Loss (kBtu/hr)	RETURN Leakage (lb/hr)	RETURN Heat Loss (kBtu/hr)
TOTALS:	0.00	0.0	0.00	0.00

Heating Distribution — Dist Options
Summary Statistics — Whole Stm Sys Old Plant

-- System Minimums/Maximums --

Maximum temperature (F):	348.1	at node N026
Maximum pressure (psig):	115.0	at node N026
Maximum delta p (psig):	40.4	at node N047
Minimum temperature (F):	39.9	at node N046 (dead end node)
Minimum pressure (psig):	74.6	at node N046 (dead end node)
Minimum delta p (psig):	20.2	at node N036

-- System Energy Balance --

Total energy produced:	146.4	MBtu/hr
Total energy consumed:	106.3	MBtu/hr
Thermal distribution losses:	22.3	MBtu/hr
Failed trap losses:	17.8	MBtu/hr
Pipe leakage losses:	0.0	MBtu/hr
Total losses:	40.1	MBtu/hr
Losses as % of production:	27.4%	

-- System Mass Flow Balance --

Total flow from plant(s):	117493	lb/hr
Total flow through consumers:	102510	lb/hr
Flow losses (pipes):	0	lb/hr
Flow losses (traps)	14983	lb/hr
Total flow losses:	14983	lb/hr
Flow losses as % of total:	13	%

Appendix I: HEATMAP Output File for 50 HDD for Low Temperature Water Distribution

Note: Manual corrections had to be applied in rollup of data on last page of reports.

Heating Distribution — Clean Start of Custormere
Node Characteristics — Whole system hot water (LTHW) test

Node	Consumer	Demand kBtu/hr	Flow (gpm)	Pressure (psig) Supply	Pressure (psig) Return	Pressure (psig) Delta	Temperature (F) Supply	Temperature (F) Return	Temperature (F) Delta
N001	Grp 2	722	19.2	68.7	58.7	10.0	221.8	146.8	75.1
N002	No connections	0	0.0	72.9	54.3	18.5	224.5	149.0	75.5
N003	No connections	0	0.0	72.6	54.6	17.9	224.5	149.4	75.1
N004	Hospital X-5226	15323	407.2	72.3	54.9	17.4	224.4	149.4	75.1
N005	Grp 3	1063	28.2	64.8	62.6	2.2	222.9	147.8	75.1
N006	No connections	0	0.0	73.0	54.2	18.8	224.6	148.8	75.8
N007	Grp 1	1947	51.8	67.1	60.3	6.9	222.8	147.8	75.1
N008	No connections	0	0.0	73.8	53.3	20.5	224.8	148.7	76.1
N009	Consumer X-5418	1880	50.0	73.6	53.6	20.0	224.7	149.6	75.1
N010	No connections	0	0.0	74.1	53.1	21.0	224.8	148.5	76.3
N011	No connections	0	0.0	71.0	56.2	14.8	224.1	148.3	75.7
N012	Grp 4	5503	146.3	69.4	57.9	11.6	223.6	148.6	75.1
N013	No connections	0	0.0	73.0	54.2	18.8	224.7	148.5	76.2
N014	Consumer X-5411	586	15.6	69.2	58.1	11.2	223.8	148.7	75.1
N015	Grp 5	6148	163.4	69.3	57.9	11.4	224.0	148.9	75.1
N016	No connections	0	0.0	74.7	52.4	22.3	224.9	148.4	76.5
N017	No connections	0	0.0	74.4	52.8	21.6	224.8	148.5	76.4
N018	No connections	0	0.0	73.4	53.8	19.6	224.7	148.4	76.4
N019	No connections	0	0.0	72.7	54.4	18.3	224.7	148.4	76.3
N020	Grp 8	4630	123.0	65.5	61.9	3.5	223.8	148.7	75.1
N021	Grp 7	5078	135.0	70.8	56.4	14.4	224.0	149.0	75.1
N022	No connections	0	0.0	74.0	53.1	20.9	224.8	148.6	76.2
N023	Grp 6.5	4490	119.3	69.3	58.0	11.3	224.2	149.1	75.1
N024	Grp 6	5067	134.7	71.7	55.5	16.3	224.1	149.0	75.1
N025	No connections	0	0.0	74.9	52.2	22.6	224.9	148.4	76.6
N026	Hot water plant 5426	-53943	-1404.8	75.0	52.1	22.8	225.0	148.4	76.6
N027	No connections	0	0.0	62.2	65.5	-3.3	222.0	146.0	76.0
N028	Grp 9	2790	74.1	61.0	66.7	-5.7	221.4	146.3	75.1
N029	No connections	0	0.0	67.5	60.0	7.5	223.7	146.8	76.9
N030	Grp 10	3949	104.9	64.1	63.6	0.5	223.0	147.9	75.1
N031	No connections	0	0.0	67.9	59.6	8.3	223.7	146.7	77.0
N032	Grp 11	844	22.4	65.3	62.4	2.9	222.6	147.6	75.1
N033	No connections	0	0.0	68.6	58.9	9.7	223.8	147.1	76.7
N034	Grp 12	3949	104.9	65.4	62.2	3.2	223.2	148.1	75.1
N035	No connections	0	0.0	69.2	58.3	10.9	224.1	147.5	76.6
N036	Grp 13	6281	166.9	67.2	60.3	6.9	223.7	148.7	75.1
N037	No connections	0	0.0	70.7	56.8	13.9	224.2	147.5	76.7
N038	Grp 14	3716	98.8	67.4	60.2	7.2	223.5	148.4	75.1
N039	No connections	0	0.0	71.1	56.3	14.8	224.3	147.5	76.8
N040	Grp 15	2523	67.1	64.9	62.7	2.1	223.5	148.4	75.1
N041	No connections	0	0.0	71.6	55.8	15.7	224.4	147.5	76.9
N042	Grp 16	3778	100.4	67.9	59.6	8.3	223.6	148.5	75.1
N043	No connections	0	0.0	72.8	54.5	18.3	224.5	147.5	77.0

N044	Grp 17	2095	55.7	68.6	58.9	9.8	223.5	148.4	75.1
N045	No connections	0	0.0	74.9	49.2	25.7	225.0	147.6	77.4
N046	No connections	0	0.0	75.0	49.1	25.8	39.9	39.9	0.0
N047	Hot water plant 5881	-55083	-1420.2	75.0	49.1	25.8	225.0	147.6	77.4

Heating Distribution
Node Characteristics

Clean Start of Custormere
Whole system hot water (LTHW) test

Node	Consumer	Demand kBtu/hr	Flow (gpm)	-- Pressure (psig) -- Supply	Return	Delta	-- Temperature (F) -- Supply	Return	Delta
N048	No connections	0	0.0	74.4	49.7	24.7	224.8	147.9	76.9
N049	Grp 18	2906	77.2	72.7	51.5	21.2	224.0	148.9	75.1
N050	No connections	0	0.0	73.8	50.3	23.5	224.7	147.8	76.9
N051	Grp 19	2095	55.7	69.8	54.4	15.4	223.8	148.7	75.1
N052	No connections	0	0.0	72.6	51.6	21.0	224.5	147.9	76.5
N053	Grp 20	2961	78.7	70.6	53.6	17.0	223.6	148.5	75.1
N054	Grp 21	4693	124.7	70.1	59.4	10.7	223.5	148.4	75.1
N055	Grp 22	11282	299.8	72.3	51.9	20.3	223.9	148.8	75.1
N056	No connections	0	0.0	74.4	50.5	23.9	224.8	147.3	77.5

TOTAL number of nodes: 56

Heating Distribution
Pipe Characteristics

Clean Start of Custormere
Whole system hot water (LTHW) test

#	Pipe	Length (ft)	Diameter (in)	Flow (gpm)	Temperature (F) Upstr	Dnstr	Heat loss (kBtu/hr)	Pressure (psig) Upstr	Dnstr
1	002-001	1189.9	2.00	19.2	224.5	221.8	27.58	72.9	68.7
2	002-003	276.7	8.00	407.2	224.5	224.5	11.13	72.9	72.6
3	002-005	1090.2	2.00	28.2	224.5	222.9	25.34	72.9	64.8
4	003-004	253.1	8.00	407.2	224.5	224.4	10.18	72.6	72.3
5	006-002	95.5	8.00	454.7	224.6	224.5	3.84	73.0	72.9
6	006-007	1946.9	3.00	51.8	224.6	222.8	47.91	73.0	67.1
7	008-006	1524.1	10.00	506.4	224.8	224.6	60.45	73.8	73.0
8	008-009	90.4	3.00	50.0	224.8	224.7	2.24	73.8	73.6
9	010-008	353.8	10.00	556.4	224.8	224.8	14.04	74.1	73.8
10	010-011	1813.0	5.00	146.3	224.8	224.1	60.44	74.1	71.0
11	010-013	436.4	5.00	179.0	224.8	224.7	14.57	74.1	73.0
12	011-012	971.4	5.00	146.3	224.1	223.6	32.28	71.0	69.4
13	013-014	369.7	1.50	15.6	224.7	223.8	7.24	73.0	69.2
14	013-015	1768.5	5.00	163.4	224.7	224.0	58.93	73.0	69.3
15	016-010	1033.2	12.00	881.6	224.9	224.8	46.92	74.7	74.1
16	016-017	586.1	10.00	512.0	224.9	224.8	23.27	74.7	74.4
17	017-018	519.7	6.00	258.0	224.8	224.7	16.23	74.4	73.4
18	017-022	186.0	6.00	254.0	224.8	224.8	5.81	74.4	74.0
19	018-019	307.4	6.00	258.0	224.7	224.7	9.60	73.4	72.7
20	019-020	1974.0	4.00	123.0	224.7	223.8	57.98	72.7	65.5
21	019-021	1345.7	5.00	135.0	224.7	224.0	44.84	72.7	70.8
22	022-023	1362.4	4.00	119.3	224.8	224.2	40.08	74.0	69.3
23	022-024	1604.8	5.00	134.7	224.8	224.1	53.50	74.0	71.7
24	025-016	232.3	14.00	1393.6	224.9	224.9	12.01	74.9	74.7
25	025-027	2349.6	1.50	11.2	224.9	217.4	45.27	74.9	62.2
26	026-025	145.4	14.00	1404.8	225.0	224.9	7.52	75.0	74.9
27	027-028	812.3	4.00	74.1	222.0	221.4	23.54	62.2	61.0
28	027-029	1216.5	3.00	-63.0	222.8	223.7	29.86	62.2	67.5
29	029-030	1270.5	4.00	104.9	223.7	223.0	37.14	67.5	64.1
30	029-031	181.6	5.00	-167.9	223.7	223.7	6.03	67.5	67.9
31	031-032	560.5	2.00	22.4	223.7	222.6	12.99	67.9	65.3
32	031-033	256.9	5.00	-190.3	223.7	223.8	8.53	67.9	68.6
33	033-034	1185.2	4.00	104.9	223.8	223.2	34.68	68.6	65.4

34	033-035	929.4	8.00	-295.3	223.8	224.1	37.27	68.6	69.2
35	035-036	922.1	5.00	166.9	224.1	223.7	30.65	69.2	67.2
36	035-037	1050.8	8.00	-462.2	224.1	224.2	42.18	69.2	70.7
37	037-038	1353.4	4.00	98.8	224.2	223.5	39.67	70.7	67.4
38	037-039	694.1	10.00	-560.9	224.2	224.3	27.47	70.7	71.1
39	039-040	1262.0	3.00	67.1	224.3	223.5	31.09	71.1	64.9
40	039-041	555.3	10.00	-628.0	224.3	224.4	21.99	71.1	71.6
41	041-042	1468.2	4.00	100.4	224.4	223.6	43.07	71.6	67.9
42	041-043	1163.5	10.00	-728.4	224.4	224.5	46.09	71.6	72.8
43	043-044	1214.7	3.00	55.7	224.5	223.5	29.94	72.8	68.6
44	043-056	3087.1	12.00	-784.1	224.5	224.8	140.02	72.8	74.4
45	045-047	79.7	14.00	-1420.2	225.0	225.0	4.12	74.9	75.0
46	045-048	639.1	8.00	336.3	225.0	224.8	25.75	74.9	74.4
47	045-055	4286.2	8.00	299.8	225.0	223.9	172.29	74.9	72.3
48	047-046	84.0	1.50	0.0	39.9	39.9	0.03	75.0	75.0
49	048-049	1158.1	4.00	77.2	224.8	224.0	34.05	74.4	72.7
50	048-050	310.0	6.00	259.1	224.8	224.7	9.68	74.4	73.8
51	050-051	1150.2	3.00	55.7	224.7	223.8	28.39	73.8	69.8
52	050-052	974.4	6.00	203.4	224.7	224.5	30.40	73.8	72.6
53	052-053	1250.3	4.00	78.7	224.5	223.6	36.69	72.6	70.6
54	052-054	2004.2	5.00	124.7	224.5	223.5	66.65	72.6	70.1
55	056-045	1036.0	12.00	-784.1	224.8	225.0	47.04	74.4	74.9

TOTAL number of pipes: 56

Heating Distribution — Clean Start of Custormere
Summary Statistics — Whole system hot water (LTHW) test

-- System Minimums/Maximums --

Maximum temperature (F):	225.0	at node N026
Maximum pressure (psig):	75.0	at node N026
Maximum delta p (psig):	25.8	at node N046 (dead end pipe)
Minimum temperature (F):	39.9	at node N046 (dead end pipe)
Minimum pressure (psig):	49.1	at node N046 (dead end pipe)
Minimum delta p (psig):	-5.7	at node N028

-- System Energy Balance --

Total energy produced:	109.0	MBtu/hr
Total energy consumed:	106.3	MBtu/hr
Thermal distribution losses:	2.7	MBtu/hr
Losses as % of production:	2.4%	

Appendix J: HEATMAP Output File for 50 HDD for High/Medium Temperature Water Distribution

Note: Manual corrections had to be applied in rollup of data on last page of reports.

Heating Distribution
Node Characteristics

Clean Start of Custormers
Whole system hot water (HTHW)

Node	Consumer	Demand kBtu/hr	Flow (gpm)	-- Pressure (psig) -- Supply	Return	Delta	-- Temperature (F) -- Supply	Return	Delta
N001	Grp 2	722	14.4	144.5	129.5	15.0	318.0	218.0	100.1
N002	No connections	0	0.0	146.8	127.1	19.7	323.8	222.6	101.3
N003	No connections	0	0.0	146.6	127.2	19.4	323.7	223.4	100.3
N004	Hospital X-5226	15323	305.4	146.5	127.4	19.1	323.6	223.5	100.1
N005	Grp 3	1063	21.2	142.3	131.7	10.6	320.2	220.1	100.1
N006	No connections	0	0.0	146.9	127.0	19.9	323.9	222.0	101.9
N007	Grp 1	1947	38.8	143.6	130.4	13.2	319.5	219.4	100.1
N008	No connections	0	0.0	148.3	125.5	22.8	324.5	221.8	102.8
N009	Consumer X-5418	1880	37.5	148.2	125.7	22.5	324.3	224.2	100.1
N010	No connections	0	0.0	148.7	125.1	23.6	324.7	221.4	103.3
N011	No connections	0	0.0	143.4	130.5	13.0	323.0	221.4	101.6
N012	Grp 4	5503	109.7	140.6	133.4	7.2	322.1	222.0	100.1
N013	No connections	0	0.0	148.1	125.7	22.4	324.3	221.5	102.8
N014	Consumer X-5411	586	11.7	147.7	126.2	21.4	322.0	222.0	100.1
N015	Grp 5	6148	122.5	146.1	132.2	13.9	322.6	222.5	100.1
N016	No connections	0	0.0	149.7	124.2	25.5	325.0	221.2	103.8
N017	No connections	0	0.0	149.1	124.8	24.3	324.7	221.3	103.4
N018	No connections	0	0.0	148.5	125.3	23.2	324.4	221.0	103.3
N019	No connections	0	0.0	148.2	125.7	22.5	324.1	221.2	103.0
N020	Grp 8	4630	92.3	144.1	129.9	14.2	322.0	221.9	100.1
N021	Grp 7	5078	101.2	144.8	129.1	15.7	322.8	222.7	100.1
N022	No connections	0	0.0	148.9	125.3	23.6	324.6	221.9	102.7
N023	Grp 6.5	4490	89.5	146.2	128.0	18.2	323.0	222.9	100.1
N024	Grp 6	5067	101.0	144.9	129.3	15.6	323.0	222.9	100.1
N025	No connections	0	0.0	149.9	124.0	25.9	325.0	220.9	104.1
N026	No connections	-57471	-1100.8	150.0	123.8	26.1	325.0	220.9	104.1
N027	No connections	0	0.0	141.9	132.1	9.8	321.3	219.1	102.2
N028	Grp 9	2790	55.6	139.1	134.9	4.2	320.0	220.0	100.1
N029	No connections	0	0.0	141.9	132.1	9.8	320.9	218.1	102.8
N030	Grp 10	3949	78.7	140.0	134.1	5.9	319.2	219.2	100.1
N031	No connections	0	0.0	142.2	131.8	10.4	321.2	217.8	103.3
N032	Grp 11	844	16.8	140.7	133.4	7.3	318.9	218.8	100.1
N033	No connections	0	0.0	142.7	131.2	11.5	321.5	218.2	103.2
N034	Grp 12	3949	78.7	140.9	133.1	7.8	319.9	219.8	100.1
N035	No connections	0	0.0	144.9	129.1	15.8	322.1	219.0	103.1
N036	Grp 13	6281	125.2	143.8	130.2	13.6	321.2	221.1	100.1
N037	No connections	0	0.0	145.5	128.4	17.1	322.6	218.8	103.8
N038	Grp 14	3716	74.1	143.7	130.3	13.4	320.8	220.7	100.1
N039	No connections	0	0.0	146.1	127.8	18.4	322.9	218.7	104.2
N040	Grp 15	2523	50.3	142.6	131.4	11.3	320.7	220.7	100.1
N041	No connections	0	0.0	146.8	127.1	19.7	323.1	218.7	104.4

N042	Grp 16	3778	75.3	144.7	129.2	15.5	321.2	221.1	100.1
N043	No connections	0	0.0	147.4	126.5	20.9	323.6	218.5	105.1
N044	Grp 17	2095	41.8	145.0	128.9	16.1	321.0	221.0	100.1
N045	No connections	0	0.0	149.9	123.9	26.0	325.0	218.9	106.1
N046	No connections	0	0.0	150.0	123.9	26.1	39.9	39.9	0.0
N047	Hot Water Plant 5881	-54161	-1017.9	150.0	123.9	26.1	325.0	218.9	106.1

Heating Distribution — Clean Start of Custormere

Node Characteristics — Whole system hot water (HTHW)

Node	Consumer	Demand kBtu/hr	Flow (gpm)	Pressure (psig) Supply	Pressure (psig) Return	Pressure (psig) Delta	Temperature (F) Supply	Temperature (F) Return	Temperature (F) Delta
N048	No connections	0	0.0	148.7	125.1	23.6	324.7	220.2	104.5
N049	Grp 18	2906	57.9	144.5	129.5	15.0	322.9	222.8	100.1
N050	No connections	0	0.0	148.4	125.5	22.9	324.5	219.9	104.6
N051	Grp 19	2095	41.8	146.1	127.8	18.3	322.1	222.0	100.1
N052	No connections	0	0.0	146.6	127.3	19.4	323.7	220.3	103.5
N053	Grp 20	2961	59.0	141.9	132.1	9.8	321.9	221.8	100.1
N054	Grp 21	4693	93.5	142.3	131.6	10.7	321.5	221.5	100.1
N055	Grp 22	11282	224.9	143.5	130.4	13.1	322.5	222.4	100.1
N056	No connections	0	0.0	149.3	124.6	24.7	324.7	217.9	106.8

TOTAL number of nodes: 56

Heating Distribution — Clean Start of Custormere

Pipe Characteristics — Whole system hot water (HTHW)

#	Pipe	Length (ft)	Diameter (in)	Flow (gpm)	Temperature (F) Upstr	Temperature (F) Dnstr	Heat loss (kBtu/hr)	Pressure (psig) Upstr	Pressure (psig) Dnstr
1	002-001	1189.9	2.00	14.4	323.8	318.0	44.11	146.8	144.5
2	002-003	276.7	8.00	305.4	323.8	323.7	23.45	146.8	146.6
3	002-005	1090.2	2.00	21.2	323.8	320.2	40.57	146.8	142.3
4	003-004	253.1	8.00	305.4	323.7	323.6	21.44	146.6	146.5
5	006-002	95.5	8.00	341.0	323.9	323.8	8.09	146.9	146.8
6	006-007	1946.9	3.00	38.8	323.9	319.5	89.71	146.9	143.6
7	008-006	1524.1	8.00	379.8	324.5	323.9	129.36	148.3	146.9
8	008-009	90.4	3.00	37.5	324.5	324.3	4.20	148.3	148.2
9	010-008	353.8	8.00	417.3	324.7	324.5	30.07	148.7	148.3
10	010-011	1813.0	4.00	109.7	324.7	323.0	98.28	148.7	143.4
11	010-013	436.4	5.00	134.2	324.7	324.3	27.24	148.7	148.1
12	011-012	971.4	4.00	109.7	323.0	322.1	52.42	143.4	140.6
13	013-014	369.7	2.00	11.7	324.3	322.0	13.81	148.1	147.7
14	013-015	1768.5	5.00	122.5	324.3	322.6	110.01	148.1	146.1
15	016-010	1033.2	10.00	661.2	325.0	324.7	103.40	149.7	148.7
16	016-017	586.1	8.00	384.0	325.0	324.7	49.86	149.7	149.1
17	017-018	519.7	6.00	193.5	324.7	324.4	36.67	149.1	148.5
18	017-022	186.0	6.00	190.5	324.7	324.6	13.13	149.1	148.9
19	018-019	307.4	6.00	193.5	324.4	324.1	21.67	148.5	148.2
20	019-020	1974.0	4.00	92.3	324.1	322.0	106.72	148.2	144.1
21	019-021	1345.7	4.00	101.2	324.1	322.8	72.86	148.2	144.8
22	022-023	1362.4	4.00	89.5	324.6	323.0	73.85	148.9	146.2
23	022-024	1604.8	4.00	101.0	324.6	323.0	86.98	148.9	144.9
24	025-016	232.3	12.00	1045.2	325.0	325.0	26.54	149.9	149.7
25	025-027	2349.6	3.00	55.6	325.0	321.3	108.82	149.9	141.9
26	026-025	145.4	14.00	1100.8	325.0	325.0	17.88	149.9	149.9
27	027-028	812.3	3.00	55.6	321.3	320.0	37.30	141.9	139.1
28	027-029	1216.5	2.00	0.0	321.3	39.9	22.89	141.9	141.9
29	029-030	1270.5	4.00	78.7	320.9	319.2	67.97	141.9	140.0
30	029-031	181.6	4.00	-78.7	320.9	321.2	9.75	141.9	142.2
31	031-032	560.5	2.00	16.8	321.2	318.9	20.71	142.2	140.7

32	031-033	256.9	4.00	-95.5	321.2	321.5	13.80	142.2	142.7
33	033-034	1185.2	4.00	78.7	321.5	319.9	63.55	142.7	140.9
34	033-035	929.4	5.00	-174.2	321.5	322.1	57.48	142.7	144.9
35	035-036	922.1	5.00	125.2	322.1	321.2	57.00	144.9	143.8
36	035-037	1050.8	8.00	-299.4	322.1	322.6	88.62	144.9	145.5
37	037-038	1353.4	4.00	74.1	322.6	320.8	72.82	145.5	143.7
38	037-039	694.1	8.00	-373.5	322.6	322.9	58.62	145.5	146.1
39	039-040	1262.0	3.00	50.3	322.9	320.7	58.18	146.1	142.6
40	039-041	555.3	8.00	-423.8	322.9	323.1	46.94	146.1	146.8
41	041-042	1468.2	4.00	75.3	323.1	321.2	79.13	146.8	144.7
42	041-043	1163.5	10.00	-499.1	323.1	323.6	115.85	146.8	147.4
43	043-044	1214.7	3.00	41.8	323.6	321.0	56.09	147.4	145.0
44	043-056	3087.1	10.00	-540.8	323.6	324.7	308.19	147.4	149.3
45	045-047	79.7	12.00	-1017.9	325.0	325.0	9.11	149.9	150.0
46	045-048	639.1	6.00	252.2	325.0	324.7	45.14	149.9	148.7
47	045-055	4286.2	6.00	224.9	325.0	322.5	301.62	149.9	143.5
48	047-046	84.0	2.00	0.0	39.9	39.9	0.04	150.0	150.0
49	048-049	1158.1	3.00	57.9	324.7	322.9	53.76	148.7	144.5
50	048-050	310.0	6.00	194.3	324.7	324.5	21.88	148.7	148.4
51	050-051	1150.2	3.00	41.8	324.5	322.1	53.29	148.4	146.1
52	050-052	974.4	5.00	152.6	324.5	323.7	60.75	148.4	146.6
53	052-053	1250.3	3.00	59.0	323.7	321.9	57.83	146.6	141.9
54	052-054	2004.2	4.00	93.5	323.7	321.5	108.19	146.6	142.3
55	056-045	1036.0	10.00	-540.8	324.7	325.0	103.68	149.3	149.9

TOTAL number of pipes: 56

Heating Distribution Summary Statistics

Clean Start of Custormere
Whole system hot water (HTHW)

-- System Minimums/Maximums --

Maximum temperature (F):	325.0	at node N026
Maximum pressure (psig):	150.0	at node N026
Maximum delta p (psig):	26.1	at node N026
Minimum temperature (F):	39.9	at node N046 (dead end pipe)
Minimum pressure (psig):	123.8	at node N026
Minimum delta p (psig):	4.2	at node N028

-- System Energy Balance --

Total energy produced:	111.6	MBtu/hr
Total energy consumed:	106.3	MBtu/hr
Thermal distribution losses:	5.3	MBtu/hr
Losses as % of production:	4.7%	

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